SEWAGE DISPOSAL AND SEWER CONSTRUCTION IN THE CITY OF MILWAUKEE

BY

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B. S., UNIVERSITY OF ILLINOIS, 1911

THESIS

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE

DEGREE OF

CIVIL ENGINEER

IN

THE GRADUATE SCHOOL

OF THE

UNIVERSITY OF ILLINOIS

1917

UNIVERSITY OF ILLINOIS

THE GRADUATE SCHOOL

May 1, 1917 191

I HEREBY RECOMMEND THAT THE THESIS PREPARED BY

RAYMOND RUDOLPH LUNDAHL

ENTITLED Sewage Disposal and Sewer Construction in the City of Milwaukee.

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE PROFESSIONAL DEGREE OF Civil Engineer

F. H. Newell

Head of Department of Civil Engineering

Recommendation concurred in:

A. P. Carman
A N Talbot

Committee

I N T R O D U C T I O N.

The question of sewage disposal in the City of Milwaukee, Wisconsin, has grown to be a momentous one, and has required much study. It is with this subject of sewage disposal that the following thesis is to deal.

Situated on the west shore of the southern end of Lake Michigan, the city draws its supply of water from the lake. Since the first system of sewers was constructed in 1869 all the sewage and manufacturing wastes have been dumped directly into the lake or into the rivers, all eventually reaching the lake. As the population has steadily increased, the pollution of the lake water and hence the city's supply of drinking water has grown enormously. Epidemics caused by impure drinking water, such as intestinal disorders and typhoid fever, have been prevalent for the last several years. The worst of these epidemics occured during the winter months of 1915 and 1916 when 411 cases of typhoid fever and 42 deaths from the disease were reported to the health department of the city.

The city is naturally divided into four divisions, the East, West, and South Sides and Bay View, by three rivers all flowing into the lake. The Milwaukee River flows from the extreme north side of the city, the Menomonee from the west side, and the Kinnickinnic from the south side all joining near the heart of the city before emptying into the lake. Naturally with the rivers located as they are, the cheapest system of sewers were those discharging directly into the rivers, but with the sickness and disease caused by the pollution of the drinking water due to this method of sewage disposal it soon became apparent that some different means must be devised to alleviate the danger and menace to the public health. It was necessary to do something that would give the city a supply of pure water for drinking purposes. With this fact in view, the present Sewerage Commission of the City of Milwaukee was created, the one purpose in mind being to devise means of properly disposing of the sewage.

It is with the work of this commission that the following "Thesis" is to deal, taking up in detail the entire project of sewage disposal in the city as carried out under the direction of the commission. It will be discussed in the following manner:

1st: The creation of the commission and the organization of its engineering department;

2nd: A descriptive outline of the work performed by the commission up to the present time, including the experiments conducted at the experimental testing station;

3rd: The new intercepting sewer system and disposal plant, giving a general discription, and taking up the questions entering into the design.

4th: Investigations, surveys, plans, contract letting, sewerage commission construction organization, contractors forces and methods used in carrying out the work of building Section No. 2 of the Menomonee Valley Low Level Intercepting Sewer, as an example of the way the construction is carried on under the direction of the commission.

5th: A summarization of the results of the work of the commission giving the present status of the work, when to be completed, and the expected results from the entire system.

I wish to acknowledge the able and willing assistance rendered and the information furnished by Mr. Darwin W. Townsend, Chief Draughtsman of the Sewerage Commission, in connection with the writing of this thesis.

Raymond R. Lundahl,

Resident Engineer.

TABLE OF CONTENTS

PART I.

HISTORICAL.

PART II.

CHAPTER I

THE SEWERAGE COMMISSION OF THE CITY OF MILWAUKEE.

PART III.

CHAPTER I

CHAPTER II

THE ACTIVATED SLUDGE PROCESS AND THE EXPERIMENTAL PLANT.

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

SEWAGE DISPOSAL AND SEWER CONSTRUCTION IN THE CITY OF MILWAUKEE WISCONSIN UNDER THE DIRECTION OF THE SEWERAGE COMMISSION CREATED IN 1913.

PART I.

HISTORICAL.

Before taking up in detail the discussion of the work of the present Sewerage Commission it is of interest to know something of the history of sewage disposal in the City of Milwaukee, Wisconsin.

Thirty-six years ago when the population of the City was 110,000, the pollution of the three rivers, due to the sewage and industrial wastes deposited therein, had become such a menace to the health and comfort of the citizens that a commission composed of three of the leading sanitary engineers of the United States was appointed to "aid in devising a scheme for abating the river nuisance."

After a careful and comprehensive study of the existing conditions, the commission recommended that a system of intercepting sewers be built along the rivers to collect the sewage and industrial wastes being discharged therein, carry it to a pumping station to be located on "Jones Island", and there discharge it into the lake south of the harbor entrance.

Following this report the citizens of Milwaukee, presented to the General Assembly of 1880, a Bill entitled, "An Act to preserve and promote the public health in the City of Milwaukee." The passage of this Act made it a misdeamor, punishable by a fine or imprisonment, for any person to deposit in the rivers within the city limits any refuse, obnoxious, odorous or unhealthful matter of any kind or nature from any manfacturing or other building of whatever kind or character.

It made it mandatory upon The Board of Public Works to provide for the care of all such unhealthful matter, by providing means for conveying it beyond the limits of the City and there disposing of it. The cost of all such works was to be met by assessing an equitable proportion to the owners or occupants of those manufacturing and industrial establishments directly contributing to the pollution of the rivers, and by levying a one mill tax upon all the property within the city.

In accordance with this Act the Board of Public Works presented a report to the Common Council, on July 19th, 1880, recommending the constructing of an intercepting sewer and pumping equipment for collecting the sewage emptying into the Monomonee River, and its slips, conveying it to "Jones Island", and there pumping it into the lake.

These recommendations were accepted and the work was completed in 1886 at a cost of $346,749.97, and resulted in a partial alleviation of the nuisance existing in the Menomonee Valley.

The conditions prevailing in the Milwaukee River grew worse as the population and number of sewer outlets increased, and in 1886 Mr. Geo. H. Benzenberg, then City Engineer, in his annual report to the Common Council, recommended that a tunnel connecting Lake Michigan with the river be built, and that about three hundred million gallons per day of cool, clear, pure lake water be pumped through this tunnel and discharged into the river so as to create a current and supply the dilution necessary to prevent the active decomposition of the sewage which was being discharged into and deposited on the bottom of the river.

He estimated that such a method would abate the nuisance in the least time and would answer all requirements for from 15 to 20 years.

Although the scheme was opposed by all the influential newspapers of the city, and by many of its influential citizens, the Common Council authorized its execution, and it was completed in September, 1888, and immediately resulted in clearing up the river and abating the nuisance which had so long existed.

Prior to the completion of the tunnel above mentioned, another commission was appointed to design "the construction of works necessary to relieve and abate the river nuisance, the collection and final disposal of all the sewage of the city, and for a supply of a sufficient quantity of pure water."

This commission was composed of Messrs. George H. Benzenberg, Thomas J. Whitman, Joseph P. Davis, and Henry Flad, all emminent engineers. In its report submitted May 21st, 1889, it recommended the construction of a system of intercepting sewers to collect all the sewage from the city and prevent it from being discharged into the rivers, conveying it to the lake at a point about six miles below the harbor entrance and discharging into the bottom of the lake from 6,000 to 8,000 feet from the shore in 30 feet depth of water. It was expected that the great dilution afforded by the lake waters would destroy the organic matters in the sewage by natural means.

At the time that this report was made the towns of Cudahy and South Milwaukee were not in existence, so there were no interests in the vicinity to be affected. The estimated cost of the work was $3,843,550.49, and the population of the city was then 210,000. It should be here noticed that this report was made after the carrying out of the Milwaukee River flushing works recommended by Mr. Benzenberg. While these works were highly successful in mitigating the nuisance, it was recommended by this commission that they were paliative only, and would not satisfactorily meet the problem as the population of the city increased.

The pollution of the Kinnickinnic River became such a nuisance to the welfare of the citizens of the south side that the Common Council, in 1897, authorized the construction of works for conveying three hundred million gallons of lake water into the river at or near Chicago Road, for the purpose of flushing this river in the same manner as had for several years been carried out with the Milwaukee River. This work was begun in 1896, but was not completed until 1907.

While these works successfully cleaned up the river, they added materially to the pollution of the lake in the vicinity of the public water intake. Dr. Bading the Commissioner of Health, aptly sums up the situation in his annual report of 1908 by the following words: "The opening of our new Kinnickinnic flushing tunnel has certainly not improved the water for drinking purposes, adding, as it does, by a number of million gallons to the already large amount of sewage that is thrown into the lake every 24 hours.

In 1909, in compliance with recommendations made to the Common Council by Dr. Bading, another commission was appointed, composed of Harrison P. Eddy, John W. Alvord, and George C. Whipple, all eminent sanitary engineers, "to make a comprehensive study of sewage disposal in the City of Milwaukee".

This commission in 1910 recommended the building of a system of intercepting sewers to collect all the sewage being discharged into the rivers and lake, conveying it to preliminary treatment works to be located on the shores of the Kinnickinnic River, between Lincoln Avenue and Chicago Road, where the most offensive solids would be removed by sedimentation, or chemical precipittation, carried by steamer far out into the lake and dumped, and the partially treated sewage to be carried to the lake through a 13 feet conduit terminating on the lake shore about four miles south of the harbor entrance, where it was to be further treated by sprinkling filters, (if the prevailing conditions warranted further treatment) and finally discharged in the bottom of the lake through a subaqueous tube terminating about 6,000 feet from the shore in a depth of about 30 feet of water.

In addition to this method of collecting and disposing of the sewage, this commission recommended the immediate construction of works for flushing out the Menomonee River and slips with lake water similar in character to those already built for flushing the Milwaukee and Kinnickinnic Rivers.

In addition to the sewage and flushing works it further recommended the immediate construction of a filter plant for treating the entire public water supply obtained from the lake.

The entire cost of the works recommended to meet the requirements for the 1950 population, was estimated to be $13,255,000.

This report brought about the preparation and passage of an Act by the General Assembly on June 30, 1913, entitled, "An Act relating to sewage disposal works in cities of the first class," authorizing the construction of such works under the general direction of a sewerage commission and providing for levying a special tax upon all property to meet the cost.

In accordance with such Act the present Sewerage Commission of the City of Milwaukee was appointed in the fall of 1913, by Dr. Bading who was then Mayor of the City.

P A R T II.

CHAPTER I.

THE SEWERAGE COMMISSION OF THE CITY OF MILWAUKEE.

I. INTRODUCTION. The problem of sewage disposal in the City of Milwaukee Wisconsin had assummed such great proportions by 1910, that some means had to be devised to care for it. A commission of emminent sanitary engineers was accordingly appointed to make a study of the question and report their findings accordingly.

This was done and their report submitted, resulted in the State Legislature passing an Act, giving the mayor authority to appoint a commission for carrying out the projects recommended in the report mentioned. This Act was passed in June 1913.

2. CREATION OF COMMISSION. According to said Act, the mayor, after the necessary resolutions had been passed by the Common Council, appointed five citizens of Milwaukee to serve as members of the Sewerage Commission and his appointments were confirmed by the Council in September 1913.

The Act requires that the appointees shall continue in office until the work of said commission in the City has been fully and finally completed in every respect. No person holding any office in any political organization or any City, County or state office other than that of a notary public is eligible to be a member of the Commission. This latter clause makes the Sewerage Commission entirely non-political and does away with the petty politics that so often creep into municipal work.

The commissioners are required to furnish a bond to the City in the sum of $10,000.00 for the faithful discharge of the duties imposed upon them. Any vacancy in the office of commissioner is filled by appointment under the same conditions as the original appointment.

3. PERSONEL. The commissioners are all highly honored citizens of Milwaukee and are considered leaders in their varied walks of life. Mr. George H. Benzenberg the chairman is a past president of the American Society of Civil Engineers, which honor alone marks him as a man highly desired for the head of the Commission. His past experience as an engineer is one of the greatest assets of the Milwaukee Sewerage Commission.

4. DUTIES OF THE COMMISSION. The duties of the Sewerage Commission of the City of Milwaukee as defined by the Act creating it are:

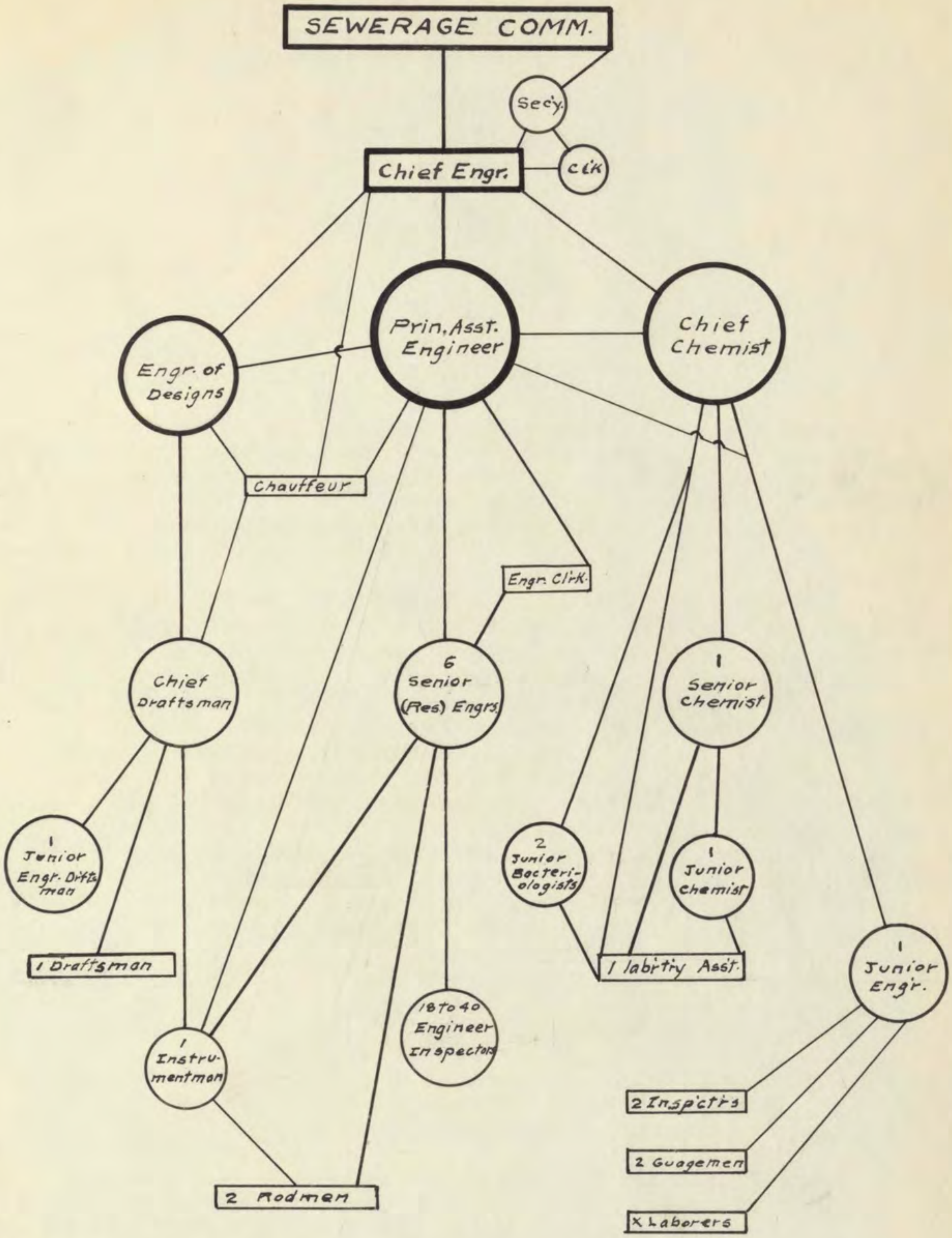
"Projecting, planning, constructing and establishing a sewerage system for the collection, transmission and disposal of the house and other sewage and drainage of the City, including, either as a combined or separate feature of said system, the collection, transmission and disposal of storm and ground water, respectively, and the Commission is clothed with every and all powers which may be necessary or proper for these purposes or either of them." A detailed account of these powers may be found by referring to Act 608 of the Laws of Wisconsin for 1913.

5. CHIEF ENGINEER. Recognizing the magnitude of the problem confronting it, the Commission immediately upon organization, proceeded to choose a Chief Engineer who should be fully experienced in the treatment and disposal of sewage. In January 1914, after careful consideration of all applications, Mr. T. Chalkley Hatton was appointed Chief Engineer at a salary of $10,000. per year for two years, with an increase to $12,000 per annum after January 31, 1916.

6. ENGINEERING DEPARTMENT ORGANIZATION. At the same time that Mr. Hatton was chosen, the Commission appointed Mr. Wm. R. Copeland then chief chemist for the Metropolitan Sewage Commission of New York City, as chief chemist in charge of the work at the experimental station. Mr. Copeland has spent over twenty years in continuous investigation of sewage and water purification and is a leading expert in this line.

Mr. D. W. Townsend, an experienced draughtsman in the preparation of plans for sewage treatment plants, was appointed special draughtsman.

Mr. Hatton reported for duty on February 2nd 1914, and with Mr. Copeland and Mr. Townsend as a nucleus, immediately began the organization of the engineering department. There have been but very few changes in the organization, except for the increase in size, since 1914. In Figure I will be found a graphic representation of the organization of the Engineering Department of the Sewerage Commission as it exists to-day. A careful study of this will give the reader a very good idea of the different divisions of the organization and of how they are related to one another.



GRAPHIC REPRESENTATION OF THE SEWERAGE COMMISSION ORGANIZATION AS IT EXISTED IN FEBRUARY 1917.

FIG. I

P A R T III.

CHAPTER I.

1. THE EXPERIMENTAL LABORATORY. The first work undertaken by the Engineering Department of the Sewerage Commission, was the planning and construction of a laboratory building. This was erected at the north end of "Jones Island" (the Island is shown in yellow on the large city map attached at the back of this thesis) and completed about May 1st, 1914.

2. DISSOLVED OXYGEN. The chief chemist and his force of assistants, began immediately to make tests for dissolved oxygen, at many points in the Milwaukee, Menomonee, and Kinnickinnic Rivers and in Lake Michigan, and also began a study and examination of the liquid effluents from the larger manufacturing plants.

Dissolved oxygen referred to above may be defined as the free or gaseous oxygen contained by water.

Lake and river waters in their normal condition are generally saturated with dissolved oxygen, but when sewage undergoing decomposition is present the dissolved oxygen disappears as the fermentation of the organic matter proceeds. Decomposition of the sewage takes place more actively in warm than in cold weather, and therefore the oxygen decreases with great rapidity in summer. If the oxygen disappears the water becomes black and foul smelling; hence, the amount of dissolved oxygen contained serves as a measure of the danger of the waters becoming a public nuisance.

The tests on the waters were made every week from June 8th to September 22nd, 1914 and the results of the analyses show:

First: That although the water flowing over the dam in the Milwaukee River, near North Avenue, was saturated with oxygen, most of it disappeared before the water reached the State Street Bridge, and little or none was found during the warmest weather, below Grand Avenue Bridge.

Second: The Menomonee was devoid of oxygen from the Twenty-seventh Street viaduct to the West Water Street bridge, except immediately after a heavy rain.

Third: The conditions were radically different in the Kinnickinnic River, as plenty of oxygen was always found from the outlet of the flushing tunnel to the junction of this river with the Milwaukee in the turning basin back of Jones Island.

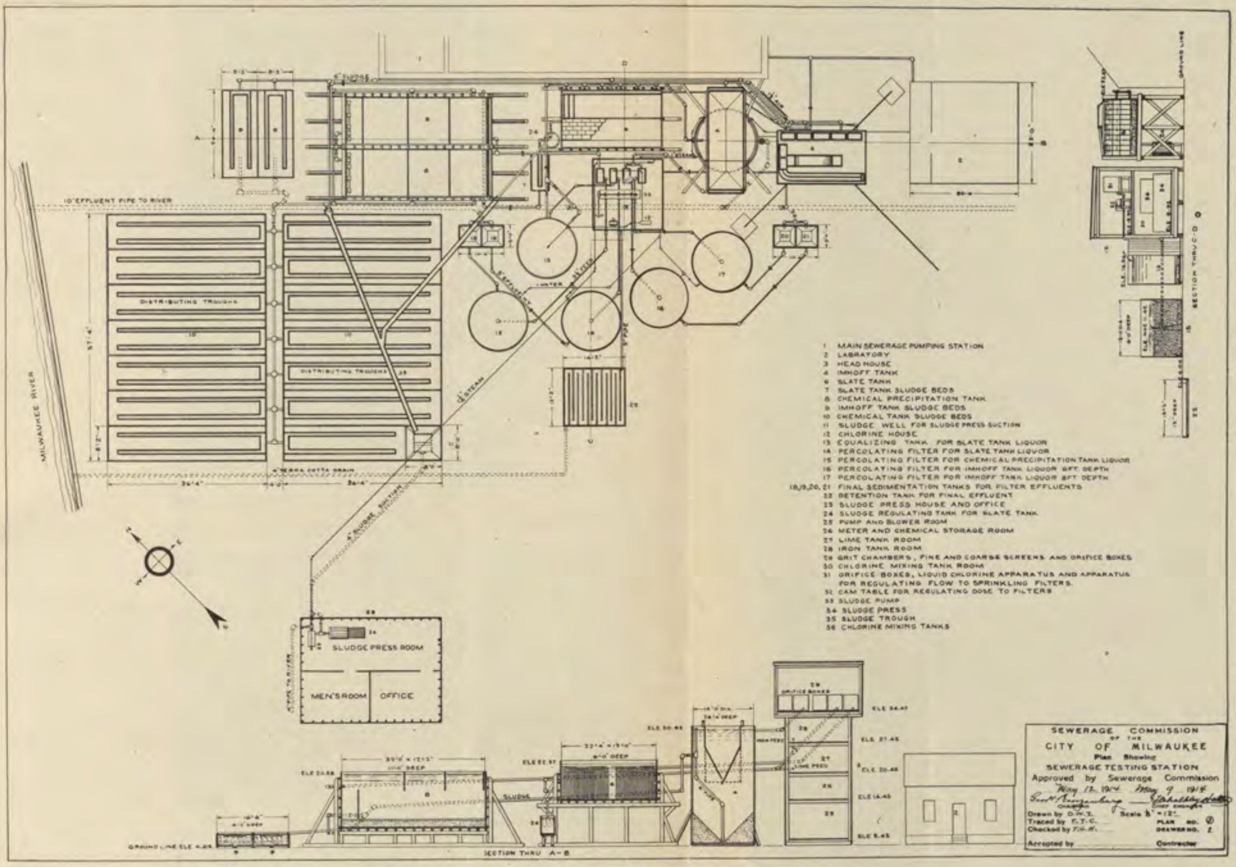
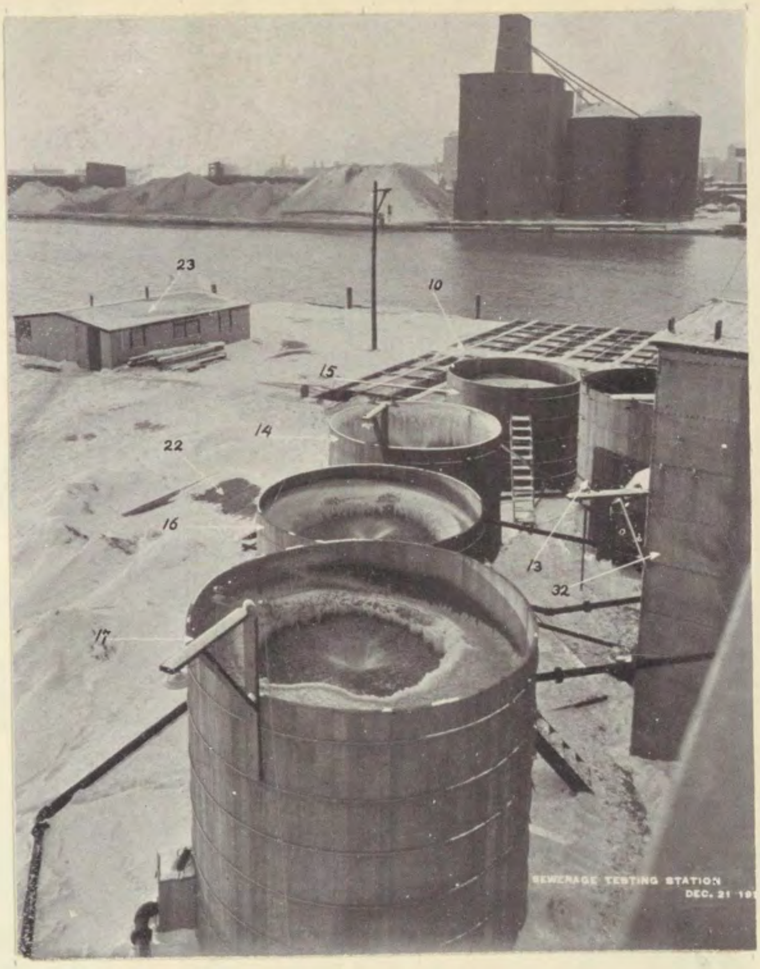

MILWAUKEE RIVER
10" EFFLUENT PIPE TO RIVER
DISTRIBUTING TROUGHS
SLUDGE PRESS ROOM
MEN'S ROOM
OFFICE
SECTION THRU A–B
SECTION THRU C–D
1 MAIN SEWERAGE PUMPING STATION
2 LABRATORY
3 HEAD HOUSE
4 IMHOFF TANK
6 SLATE TANK
7 SLATE TANK SLUDGE BEDS
8 CHEMICAL PRECIPITATION TANK
9 IMHOFF TANK SLUDGE BEDS
10 CHEMICAL TANK SLUDGE BEDS
11 SLUDGE WELL FOR SLUDGE PRESS SUCTION
12 CHLORINE HOUSE
13 EQUALIZING TANK FOR SLATE TANK LIQUOR
14 PERCOLATING FILTER FOR SLATE TANK LIQUOR
15 PERCOLATING FILTER FOR CHEMICAL PRECIPITATION TANK LIQUOR
16 PERCOLATING FILTER FOR IMHOFF TANK LIQUOR 6FT. DEPTH
17 PERCOLATING FILTER FOR IMHOFF TANK LIQUOR 8FT. DEPTH
18,19,20, 21 FINAL SEDIMENTATION TANKS FOR FILTER EFFLUENTS
22 DETENTION TANK FOR FINAL EFFLUENT
23 SLUDGE PRESS HOUSE AND OFFICE
24 SLUDGE REGULATING TANK FOR SLATE TANK
25 PUMP AND BLOWER ROOM
26 METER AND CHEMICAL STORAGE ROOM
27 LIME TANK ROOM
28 IRON TANK ROOM
29 GRIT CHAMBERS, FINE AND COARSE SCREENS AND ORIFICE BOXES
30 CHLORINE MIXING TANK ROOM
31 ORIFICE BOXES, LIQUID CHLORINE APPARATUS AND APPARATUS FOR REGULATING FLOW TO SPRINKLING FILTERS.
32 CAM TABLE FOR REGULATING DOSE TO FILTERS
33 SLUDGE PUMP
34 SLUDGE PRESS
35 SLUDGE TROUGH
36 CHLORINE MIXING TANKS
SEWERAGE COMMISSION
OF THE
CITY OF MILWAUKEE
Plan Showing
SEWERAGE TESTING STATION
Approved by Sewerage Commission
May 17 1914 May 9 1914
CHAIRMAN
CHIEF ENGINEER
Drawn by D.W.T.
Scale 1/8" = 12"
Traced by E.T.C.
PLAN NO. 2
Checked by T.C.H.
DRAWER NO. 1
Accepted by
Contractor

FIG II


23
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SEWERAGE TESTING STATION
DEC. 21 191


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FIG III

Fourth: In the hottest weather the oxygen is exhausted from the inner harbor even as far out as the outlet of the channel into Lake Michigan, over 2000 feet from shore.

These conditions were especially pronounced when the North Point Flushing Tunnel was shut down. During such periods the foul odors of the Milwaukee river spread from Broadway to Third Street.

3. THE SEWAGE TESTING STATION. The next step of the department was the construction of a sewage testing station, also located on Jones Island, which was completed and put in operation in September 1914. The chemistry force has spent most of its time since then operating the station and securing the necessary data therefrom.

A plan showing the layout of the sewage testing station and two photographic veiws of it, taken from the 1914, report of the Commission, are to be found in Figures II and III.

In order to obtain a sewage for experimental work which would fairly represent that which would ultimately have to be treated the sewage testing station was located near the terminal pumping station of the "old" Menonmonee River Intercepting Sewer. This sewer aside from the usual domestic flow carried liquors from leather manufacturing plants, soap works, packing houses, breweries, dye works, gas works, malting houses and other varied industries, and therefore gave very fair samples to be tested.

The types of sewerage purification to be tested, were selected carefully by the commission. The Imhoff, Chemical Precipitation, and State Tank systems were all tried out in 1914. Results of the tests may be found in detail in the published annual report of the Commission for 1914.

In 1915 the experiments were continued and a resumé of those tried out during the year is as follows:

Fine and coarse screening.
Grit Chambers.
Sedimentation and sludge digestion in Imhoff Tank.
Colloidal treatment by Slate Tanks.
Chemical precipitation using lime and iron.
Electrolytic treatment by Lautzenheiser Process.
Percolating filters and final sedimentation.
Sterilization by Liquid Chlorine.
Activated Sludge Process by fill and draw method.
" " " " continuous flow "
Dehydrating sludge, by pressing, gravity, and by draining on beds.

4. ACCEPTED DESIGN. As a result of the experiments conducted the design accepted for the disposal of the sewage, is that of the Activated Sludge Process by continuous flow.

The experiments on this process began in the laboratory by means of two glass tubes six feet long in which the raw sewage was placed intermittently and aerated for several different periods. The results were so promising and unusual that one of the chemical precipitation tanks was converted into an Activated Sludge tank and operated on the fill and draw principle. This tank is shown on Plate 7, on the following page, taken from the 1915 report of the commission.

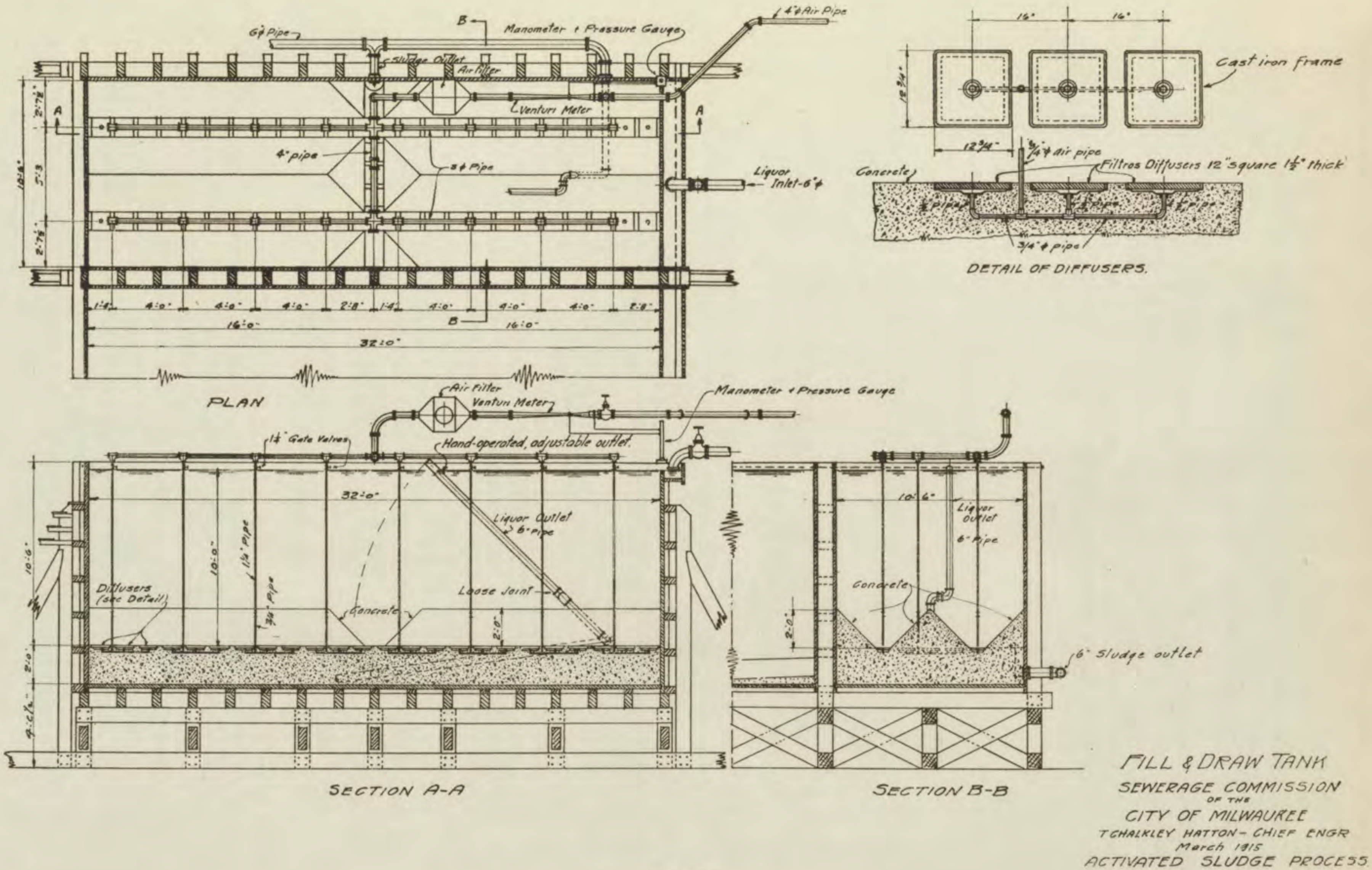


PLATE 7

Showing plan of No. 1 "Fill and Draw" Tank, used for experimental purposes exclusively. Capacity about 22,600 gallons.

The records obtained by operating the tank on the fill and draw principle were so astonishing, that it was decided to try the process by continuous flow. This was done and a better effluent produced, at less cost than any other process tried out at the Testing Station.

This is the first continuous flow tank, operated with the Activated Sludge process and has been visited by hundreds of people interested in the treatment of sewage. The universal opinion, is that it was producing the best effluent ever known upon the area required. Plate 8, from the commissions report, gives the details of this tank.

CHAPTER II.

THE ACTIVATED SLUDGE PROCESS AND THE EXPERIMENTAL PLANT.

5. DEFINITION. A brief definition of the activated sludge process as given by the chief chemist in his annual report for 1915 is as follows:-

"The sludge embodied in sewage, and consisting of suspended organic solids, including those of a colloidal nature, when agitated with air for a sufficient period, assumes a flocculent appearance very similar to small pieces of sponge. Aerobic and facultative aerobic bacteria gather in these flocculi in immense numbers, from 12 to 14 million per c. c.; some having been strained from the sewage, and others developed by natural growth. Among the latter are species which possess the power to decompose organic matter, especially of an albumoid or nitrogeneous nature, setting the nitrogen free; and others, absorbing this notrogen, convert it into nitrites and nitrates. These biological processes require time, air and favorable environments, such as suitable temperature, food supply and sufficient agitation to distribute them throughout all parts of the sewage."

"Before the process can be satisfactorily carried on the sludge must be "activated"; that is it must be alive with the aerobic nitrifying bacteria which play the most important part in the process, or in other words, the nitrogen cycle must be established, and this cycle must be maintained."

6. CREATION OF ACTIVATED SLUDGE. Activated sludge may be built up from several sources. Where the sludge retained in a final sedimentation tank from percolating filters, is available, it is one of the best seeds for starting activated sludge, because it is already activated with aerobic bacteria from the filters. An anaerobic sludge from Imhoff tanks can be turned into an aerobic activated sludge by using sufficient air during long periods; or the sludge present in the raw sewage can be built up to activated sludge by using sufficient air and sewage on the fill and draw principle."

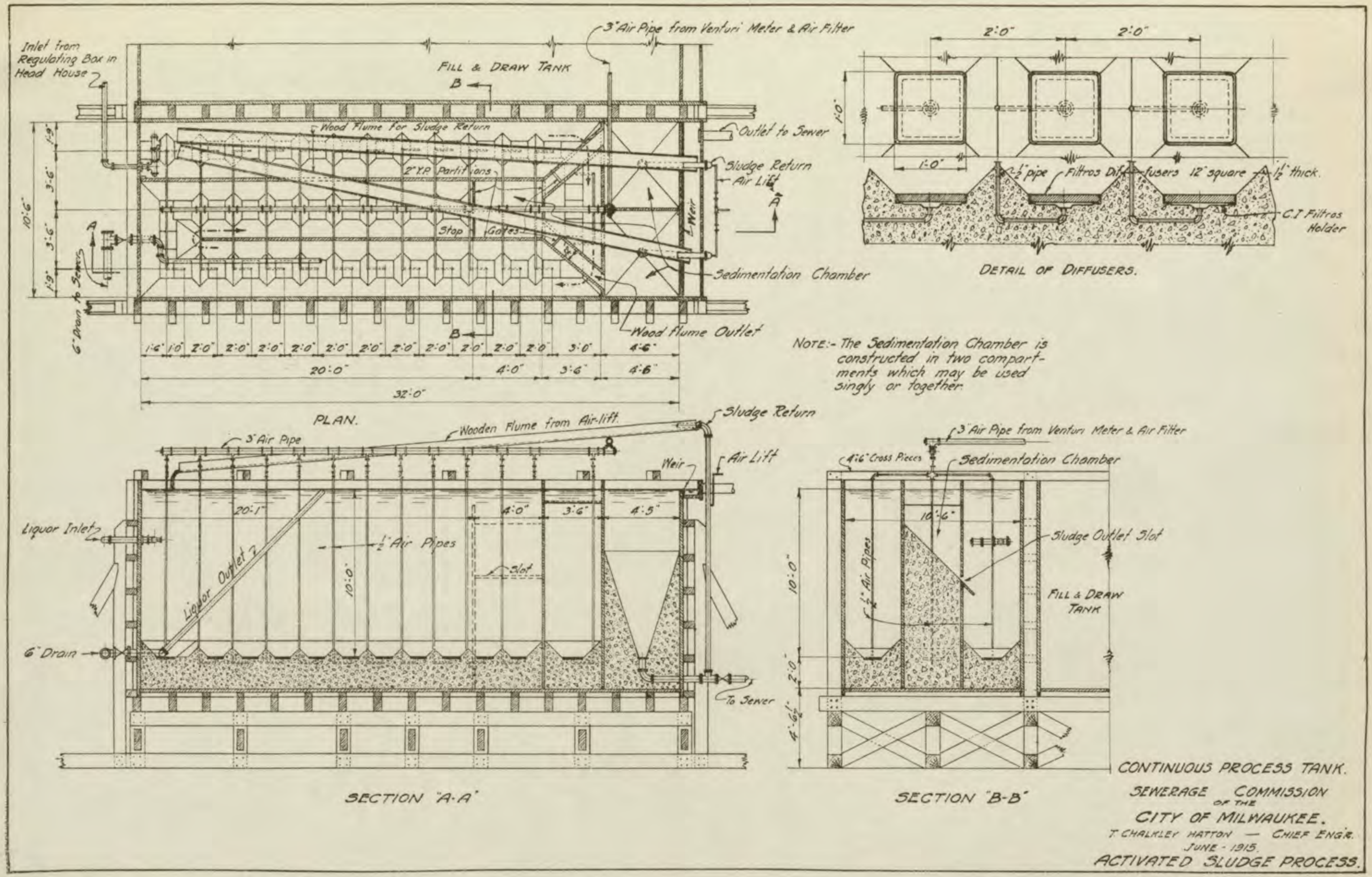


PLATE 8

Showing plan of No. 2 "Continuous Flow" Tank, used for experimental purposes exclusively. Capacity about 22,600 gallons.

7. COMPARATIVE COSTS OF OPERATION. Table 1 gives the comparative costs of operating the various sewage treatment processes, tried out at the testing station, under Milwaukee conditions, and the standard of effluents produced. From this table it is obvious that only two of the processes should be considered, namely, the activated Sludge process by continuous flow and the Imhoff tank followed by 6 feet filters, when the effluent produced and the cost of production are considered.

8. COMPARISON OF IMHOFF TANK TREATMENT AND ACTIVATED SLUDGE PROCESS. While the Imhoff tank treatment alone is the cheapest, the character of effluent produced is not such as to permit it being discharged into the lake, unless its point of discharge was far removed from the harbor entrance and water supply.

The effluent produced by sterilizing Imhoff tank effluent might be discharged into the lake outside the breakwater line, without endangering the health of the community, but the enormous quantity of solids in suspension would cause deposits on the lake bottom to which serious objections might be made by the Federal Government and would discolor the lake waters over quite a territory.

The process removes from the raw sewage a little over half of the suspended solids. The solids which are retained by the process in the form of sludge, have not sufficient available value to warrant their reduction into a fertilizer of marketable quality. The disposal of this sludge would become a very expensive operation no matter what method was used, and would also create offensive odors at times.

Sprinkling filters for a plant to care for the 1950 population would occupy 85 acres which would have to be recovered from the lake front, and would seriously interfere with the harbor developments, and the odor which necessarily arises from sprinkling filters would create a very objectionable nuisance.

In addition to these objections, is the important one of cost. For the 1950 population the annual cost would be 96 cents per capita whereas the cost of the activated sludge process would only be 53 cents per capita.

The activated sludge process would require only about 20 acres for the entire plant and produces an effluent almost free of suspended matter and nearly as clear as the lake water. This process also removes 95% of the bacteria contained in the raw sewage.

It produces a sludge high in grease and nitrogen, both of which can be made available as a marketable product of sufficient value to diminish, to a considerable extent, the annual cost of operation. No ground or other means are required, for sludge disposal, and the process is entirely free from objectionable odors, providing the plant is properly operated.

9. CONCLUSIONS. All the foregoing objections and points of favor seemed to point to the activated sludge process as the proper method of sewage disposal.

TABLE No. 1

SHOWING COMPARATIVE APPROXIMATE COST OF OPERATING CERTAIN SEWAGE TREATMENT PROCESSES UNDER MILWAUKEE CONDITIONS AND STANDARD OF EFFLUENTS PRODUCED

						**COST PER MILLION GALLONS			
	Per Cent Removal		Parts per Million						
Process-	Suspended Matter	Bacteria at 20 c	Nitrogen as Nitrates	Oxygen Consumed	Stability in Hours	Disposal of Sludge	Int. and Dep. on Cost of Plant at 7½ %	Cost of Operation Exclusive of Sludge	Total Cost
Sedimentation Imhoff	55	11.6	0.51	92	3	1.65	2.55	2.00	6.20
Imhoff with Sterilization-------------	55	85.0			42	1.65	2.61	2.25	9.51
Imhoff with six feet Sprinklers---------	53	31.5	2.64	67	62	1.65	7.00	2.50	11.15
Chemical Precipitation	78	91.9	0.98	76	15	3.65	3.04	14.00	20.69
Chemical Precipitation with Sterilization---------------	78	99.0				3.65	3.10	14.25	24.00
Chemical Precipitation with six feet Sprinklers-----------	83	36.4	1.30	61	17	3.65	7.51	14.50	25.66
Sedimentation Slate Beds-----------------	81	9.2	0.09	64	11	2.10	7.70	3.00	12.80
Slate Beds with Sterilization--------						2.16	7.76	3.25	16.11
Slate Beds with six feet Sprinklers-----	82	30.3	1.28	53	99	2.10	12.11	3.50	15.80
Activated Sludge Continuous Flow-----	94	95.5	5.94	22	116	*3.00	2.81	2.00	7.81

* The value recoverable from the activated sludge is expected to exceed the cost of disposal.

** The items entering into the costs which are common to all processes, such as pumping, cost of land, outfall conduit, etc., have been omitted from these comparative estimates.

10. NECESSITY OF EXPERIMENTAL PLANT. After conducting experiments upon the treatment of sewage by the Activated Sludge Process for three months, and securing such promising results, the Sewerage Commission deemed it expedient to try out the process upon such a workable scale as would fairly represent the conditions existing in a complete plant.

The results obtained by the small tanks as operated, could not be taken as entirely representative of what might be expected in a complete plant, because only a portion of the day's sewage was being treated, and, as the character of the sewage fluctuated widely throughout the city, and, in fact, throughout the days of the week, determinations made upon the basis of such results might be entirely erroneous.

The indications deduced from the experiments seemed to point to the necessity of maintaining an intimate contact between the activated sludge, sewage and air from three to four hours. This could be secured in the experimental tank by the fill and draw method, but if the continuous flow method was to be successfully demonstrated, length of flow must be secured as an important factor in the process, and this could only be secured by building sufficient area to get the length.

11. THE EXPERIMENTAL PLANT. It was decided to build a plant on Jones Island, upon lands owned by the City, and adjacent to the testing station. The plant was accordingly built and the capacity fixed at two million gallons per day based upon a 3-1/2 hour running through period with 25% activated sludge capacity in the aerating tanks, and to be operated on the continuous flow principle. Figure 3 A is a plan showing the general layout of the plant.

The plant consists of eleven circular reinforced concrete tanks, 30 feet in diameter and 13 feet deep, with the necessary baffle walls and appurtenances. Eight tanks are used for aerating two for sludge aeration and one for final sedimentation. The velocity through the tanks is about 5 feet per minute. The plant occupies about four tenths of an acre.

All of the tanks except the final sedimentation tank are divided by baffle walls which makes a spiral running through chamber about 6 feet wide and 114 feet long. Each chamber has a sloping bottom in the apex of which 12x12 inch filtros plates are set in castings built in units containing from five to seven plates. These castings have an air duct cast in them which discharges the air through a brass orifice to the under side of the plate. This orifice is designed to pass two cubic feet of air per minute under 5 pounds pressure per square inch. This capacity being based upon experiments showing maximum air required to be 25 cubic feet per minute per square foot of tank surface.

The baffle walls mentioned are two inches thick in the aerating tanks, built of Hyrib plastered with cement mortar. Those in the two sludge tanks are six inches thick built of the same material. The photograph on page____ shows these baffle walls very distinctly. The extra thickness here is necessary because each of the sludge tanks is divided into two distinct compartments permitting one compartment to be emptied while the other is being filled and aerated.

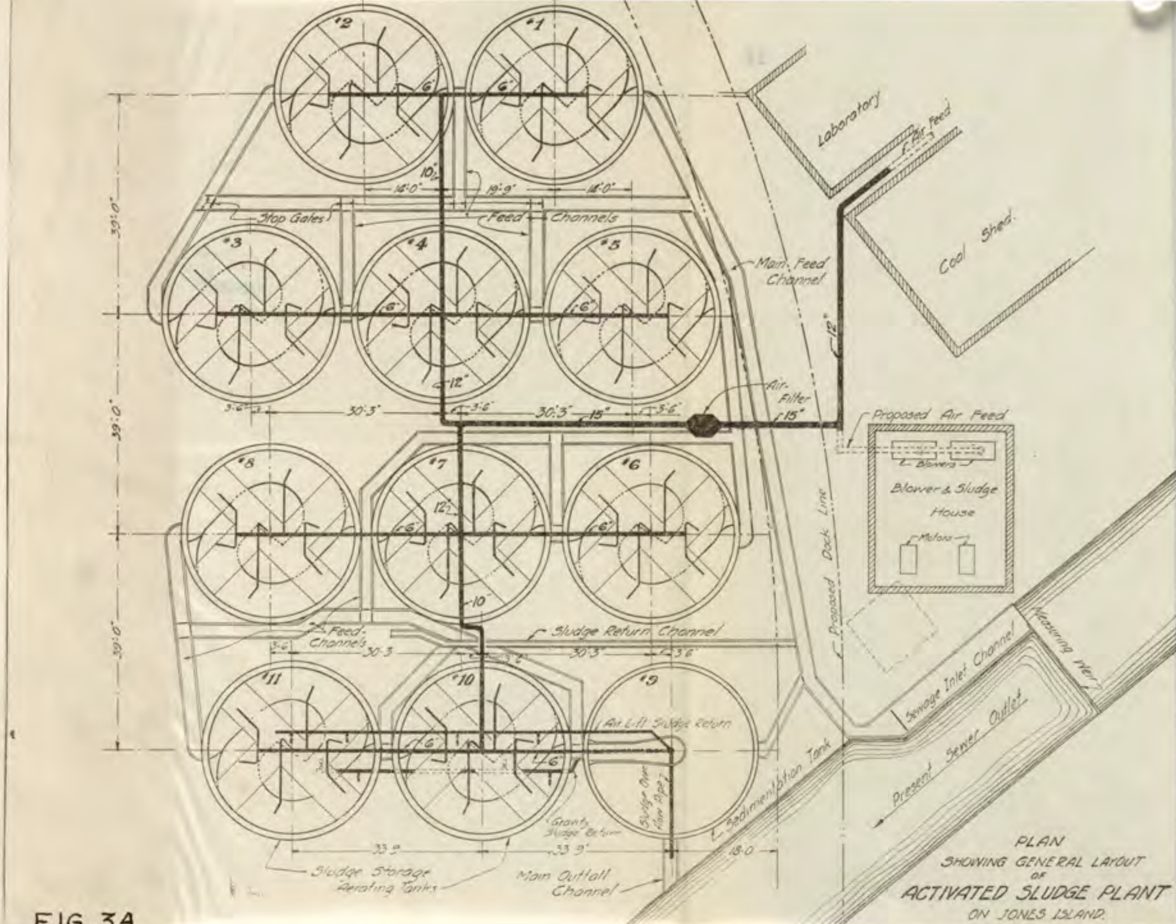
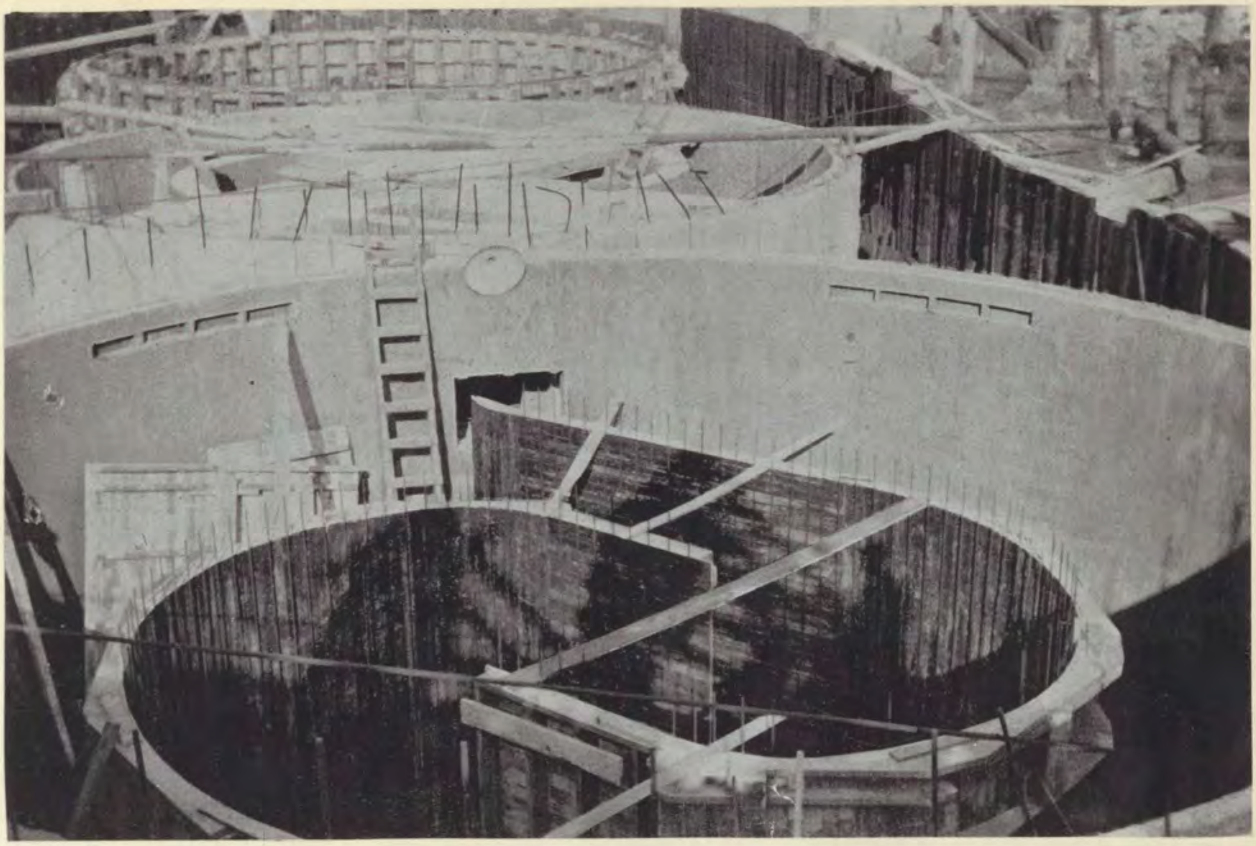

#2
#1
#3
#4
#5
#8
#7
#6
#11
#10
#9
Laboratory
Air Feed
Coal Shed
Stop Gates
Feed Channels
Main Feed Channel
Air Filter
Proposed Air Feed
Blowers
Blower & Sludge House
Motors
Proposed Dock Line
Sludge Return Channel
Feed Channels
Sewage Inlet Channel
Measuring Weir
Air Lift Sludge Return
Sludge Over flow Pipe
Sedimentation Tank
Present Sewer Outlet
Gravity Sludge Return
Sludge Storage Aerating Tanks
Main Outfall Channel
39'0"
39'0"
39'0"
14'0"
19'9"
14'0"
30'3"
30'3"
3'6"
33'9"
33'9"
18'0"
PLAN
SHOWING GENERAL LAYOUT
OF
ACTIVATED SLUDGE PLANT
ON JONES ISLAND

FIG. 3A



PHOTOGRAPH SHOWING THE BAFFLE WALLS IN THE TANKS OF THE EXPERIMENTAL DISPOSAL PLANT AS THE TANKS WERE BEING CONSTRUCTED

The sedimentation tank is built with a hopper bottom terminating in a four feet diameter cast iron pipe 24 feet below the bottom of the tank, from near the bottom of which a 12 inch pipe extends to the top of the tank. Inside this 12 inch pipe is a 1 inch pipe for delivering air to the sludge by which it is lifted from the bottom of the large cast iron pipe and delivered to the sludge tanks, or to the sludge presses.

Around the sedimentation tank a brass weir is built into the concrete, and one foot back of the weir a galvanized iron baffle plate extending six inches deep in the liquor surrounds the tank.

12. GENERAL DATA OF EXPERIMENTAL PLANT. A resume of the general data of the experimental plant as given by the chief engineer, is as follows:-

Eight aerating tanks 30 feet diameter.
Two aerating sludge tanks 30 feet diameter.
One sedimentation tank 30 feet in diameter.
Top of walls of tank 13 feet above inner bottom.
Elevation of bottom of No. 1 tank is -9.2
Elevation of water level in No. 1 tank is 0.8
Elevation of weir in sedimentation tank is 0.5
Total fall of water surface through tanks is 0.3feet.
Norman elevation of lake level is -1.4.
Depth of water and sludge in each of the 10 tanks is 10 feet

Average depth of water and sludge in the 10 tanks is 9 feet
Liquid capacity of each of the 8 aerating tanks is 45,000 gallons.
Total liquid capacity of the 8 aerating tanks is 360,000 gallons.
Capacity of each sludge tank is 44,200 gallons.
Capacity of sedimentation tank is 33,000 gallons.
Depth of sludge and water in sedimentation tank below water level is 35.2 feet.
Capacity of 48 in. cast iron pipe in bottom of sedimentation tank is 2,269 gallons.
Total open area of each aerating tank is 662.84 square feet
Total open area of 8 aerating tanks is 5302.72 square feet.
78 Filtros plates 12 inches square in each aerating tank.
Ratio of diffusing surface to tank surface is 1 to 8.5.
Estimated capacity of filtros plates in the two sludge tanks is 12 cu. ft. of air per minute under 2 inch water pressure.
Estimated capacity of filtros plates in 8 aerating tanks is 2 cu. ft. of air per minute under a 2 inch water pressure.
Total lineal feet of direct travel through eight aerating tanks is 912 feet.
Capacity of plant when operating with 25% activated sludge in aerating tanks and with 4 hours running through period is 1,620,000 gallons per day, 27 minutes sedimentation period. Velocity of liquor through tanks 3.8 feet per minute.
Capacity of plant when operating with 25% activated sludge in aerating tanks and with 3 hours running through period is 2,160,000 gallons per day, 20 minutes sedimentation period. Velocity of liquor through tanks 5 feet per minute.
Capacity of plant when operating with 20% activated sludge in aerating tanks with 3 hours running through period is 2,304,ooo gallons per day, 19 minutes sedimentation period. Velocity of liquor through tanks about 5 feet per minute.
Total ground area of plant four-tenths of an acre or two-tenths per million gallons.

13. EXPERIMENTAL CONCLUSIONS. It is believed that an excessive aeration of the sludge returned to the aerating tanks will reduce the quantity of air necessary to treat the entire body of the sewage as it passes through the tanks. If this is true a large quantity of air will be saved because there is only 25% of the total mixture of sewage and sludge to be given excessive aeration.

In this connection it has been found when a sludge high in nitrates is mixed with fresh sewage, it requires less air and less time to reduce the free ammonia in the sewage to ammoniacal nitrogen, remove the bacteria and produce a clear effluent.

14. SOURCE OF SEWAGE BEING TESTED. The sewage being treated in this plant is taken from the outlet of the "old" Menomonee River intercepting sewer. Some of this sewage originates seven miles above the outlet of the sewer and is quite septic when it reaches the treatment works.

The sewage before entering the disposal plant passes over a weir which is at the same elevation as the large weir over which the entire contents of the sewer passes. Thus the fluctuations of flow in the sewer, which discharges 12,000,000 gallons per day, are transmitted through the plant as they would be if the plant was large enough to take the entire flow from the Sewer. The weir is set to discharge the average flow required in the plant.

A liquid recording guage measures the flow over the weir, and another the total flow in the main sewer.

15. OPERATION. The operation of the plant as described by the chief engineer in his report is given here with due apologies:-

"The eight aerating tanks were first seeded with a small portion of well activated sludge, which had been prepared in outside temporary tanks, and from this seed the sludge was built up with raw sewage until it comprised about 25% of the contents passing through the tanks.

The sewage, after passing over the raw sewage weir, passes through a conduit to No. 1 aerating tank. On its way activated sludge is added in the proportion of 1 to 4, or 1 to 5, according to the experiment being conducted. The mixture of sludge and sewage passes through each of the eight aerating tanks in rotation, during which time it is agitated and oxydized by the air blown through the diffusers in the bottom of the tank, and passes into the center of the sedimentation tank in which the sludge rapidly separates from the liquor and precipitates to the bottom of the tank and into the four feet cast iron pipe, the clear liquor passing over the weir and into the lake.

The 35 feet pressure head upon the precipitated sludge in the sedimentation tank reduces its moisture content and it is then lifted by an air lift and discharged into one of the sludge compartments of the sludge tanks where it is further aerated until delivered into the raw sewage conduit.

The excess sludge not needed for keeping the aerating tanks properly seeded, is passed into the sludge treatment processes which have not been fully worked out.

By means of a float resting in a stilling chamber connected with the raw sewage weir the quantity of air necessary to pump the sludge from the sedimentation chamber to the sludge aerating chamber is controlled so as to deliver the proper proportion of sludge to the raw sewage corresponding with its rate of flow.

From observations made of the fluctuations of flow over the raw sewage weir a curve has been worked out to show the rate of air to be applied during the different periods of the day. This rate is controlled by the speed of the motor, which is variable, and is set by the man in charge of operation according to the curve.

Subsequent operation of the plant may disclose the necessity for varying the rate of air in accordance with the varying strength of the liquor, or making a variation in the activated sludge content, in order to get the greatest efficiency from the least air."

When this plant was designed no experiments had been conducted along the lines of continuous flow, and some of the parties engaged in making experiments with the process upon the fill and draw principle had expressed their doubts as to the success of the continuous flow principle.

It was therefore deemed a wise precaution to design the tanks so that they could be converted into an Imhoff tank installation with the least amount of change, or into two story continuous flow tanks for activated sludge process, should this prove successful. This explains the reason for circular tanks and controlled the depth at which they were constructed.

All of the tanks, except the sedimentation tank, are open so as to subject them to the full effects of the cold temperatures of a Wisconsin climate. It seems very important to learn what effect low temperatures will have upon the process. If the process is found to be affected to a material extent by this condition the tanks will have to be roofed and heated a few months of the year. This will add to the cost of construction and operation. It is necessary to cover the sedimentation tank to avoid the freezing of the thin film of liquor passing over the weir, causing uneven currents to be set up in the tank.

CHAPTER III.

THE PROPOSED DISPOSAL PLANT.

16. LOCATION. Jones Island, was the logical place for the location of the Proposed Sewage Disposal Plant, because the city already owned considerable property at the northern end of it. It being located near the Lake and at a minimum low level, less sewage would have to be pumped with the plant located at this place, than at any other available site. "Jones Island" (it is shown on the large City Map attached) is not really an island but a peninsula connected to the main city at the south end of the "Island" This made it accessible by either land or water which was an added point in its favor. The "Island" is bounded on the east by Lake Michigan, on the north by the Milwaukee River or Harbor Entrance and on the west by the Kinnickinnic River.

The disposal plant is to be located at the extreme north end of the island. The plan in Figure IV is a tentative layout of the proposed plant, and shows the old city property and the new that is now being acquired by condemnation proceedings. A considerable portion of the plant will be built on made ground in Lake Michigan. All the land outside of the heavy dot and dash line is to be removed by the government in connection with the Harbor improvement plans. This will not be undertaken however until the disposal plant is completed and in operation.

The present experimental unit is made up of circular tanks, whereas the new system as planned will utilize rectangular tanks. These will be more economical, as they are easier to build, will waste less ground, are more efficient and will cost less.

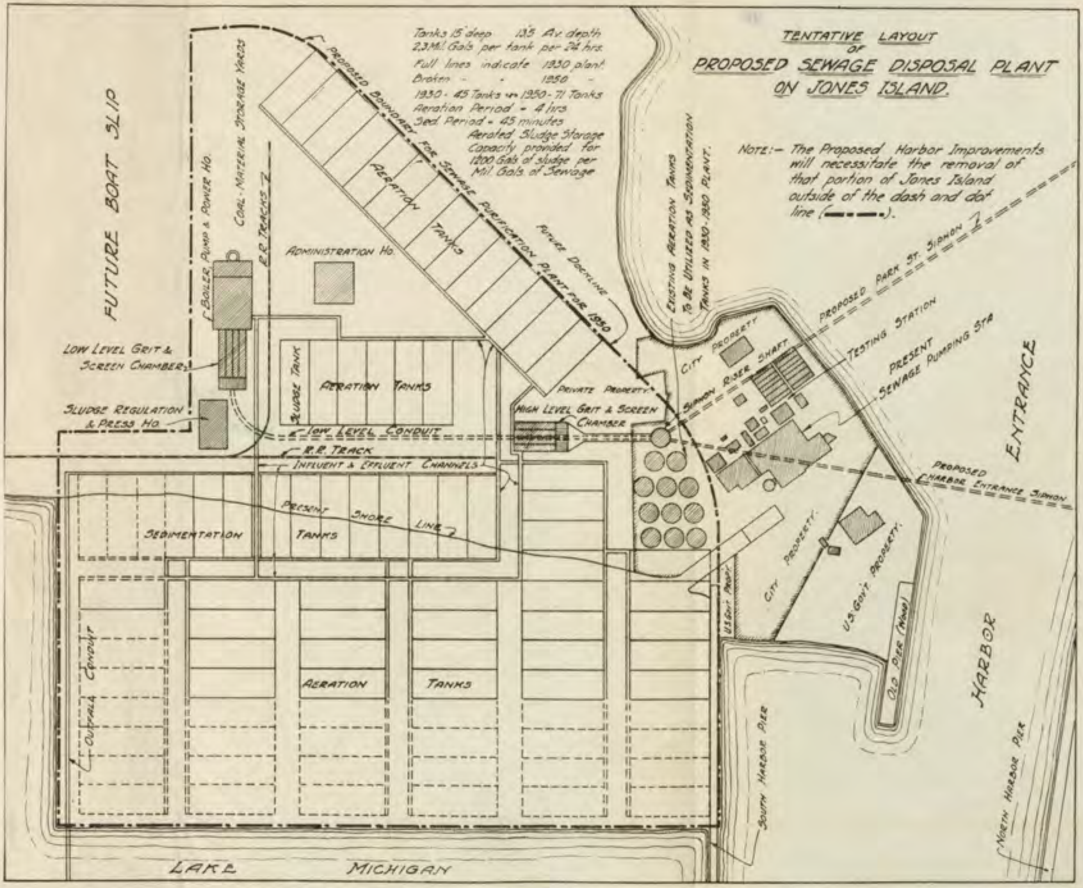

TENTATIVE LAYOUT OF PROPOSED SEWAGE DISPOSAL PLANT ON JONES ISLAND.
Tanks 15' deep 13.5' Av. depth
2.3 Mil. Gals per tank per 24 hrs.
Full lines indicate 1930 plant.
Broken - - 1950 -
1930 - 45 Tanks - 1950 - 71 Tanks
Aeration Period = 4 hrs
Sed. Period = 45 minutes
Aerated Sludge Storage Capacity provided for 1200 Gals of sludge per Mil. Gals. of Sewage
NOTE:- The Proposed Harbor Improvements will necessitate the removal of that portion of Jones Island outside of the dash and dot line (— - —).
FUTURE BOAT SLIP
BOILER, PUMP & POWER HO.
COAL-MATERIAL STORAGE YARDS
R.R. TRACKS
PROPOSED BOUNDARY FOR SEWAGE PURIFICATION PLANT FOR 1930
AERATION TANKS
FUTURE DOCKLINE
ADMINISTRATION HO.
EXISTING AERATION TANKS TO BE UTILIZED AS SEDIMENTATION TANKS IN 1930-1950 PLANT.
LOW LEVEL GRIT & SCREEN CHAMBER
SLUDGE TANK
AERATION TANKS
PRIVATE PROPERTY
CITY PROPERTY
SIPHON RISER SHAFT
PROPOSED PARK ST. SIPHON
TESTING STATION
PRESENT SEWAGE PUMPING STA.
SLUDGE REGULATION & PRESS HO.
HIGH LEVEL GRIT & SCREEN CHAMBER
LOW LEVEL CONDUIT
R.R. TRACK
INFLUENT & EFFLUENT CHANNELS
ENTRANCE
PROPOSED HARBOR ENTRANCE SIPHON
SEDIMENTATION
PRESENT SHORE LINE
TANKS
CITY PROPERTY
U.S. GOV'T PROPERTY
U.S. GOV'T PROP.
CITY PROPERTY
OLD PIER (WOOD)
HARBOR
OUTFALL CONDUIT
AERATION TANKS
SOUTH HARBOR PIER
NORTH HARBOR PIER
LAKE MICHIGAN

FIG. IV

CHAPTER IV.

SYSTEM OF SEWERS.

17. GENERAL DESIGN. No better description of the General Design of the system can be given than that of Mr. Hatton in his annual report to the Sewerage Commission, for 1915. It is therefore given here, with due apologies to Mr. Hatton.

"The city is divided into four distinct and separate water sheds drained by Lake Michigan, the Milwaukee, Menomonee and Kinnickinnic Rivers. Bordering upon the lake in the south-eastern section of the city, and upon each of the rivers, the land is too low to permit the sewage collected to be delivered by gravity at disposal works built on Jones Island; whereas the sewage collected from the balance of the land lying within the probable 1950 limits can be delivered by gravity at these works; thus the intercepting sewer system has been divided into two parts, consisting of a low and high level system.

The approximate topographical contour dividing the two systems has an elevation of 35. Based upon the total run-off through the sewers the maximum low level run-off in 1950 will be 65,445,000 gallons per day and the maximum high level run-off 165,565,000 gallons per day.

The hydraulic grade elevation at the disposal plant of the low level system is minus 16, or 16 feet below city datum.. The elevation of the water surface in the disposal plant has been fixed for the present at least, as plus 5, requiring a 21 feet lift for the low level sewage.

The hydraulic grade elevation at the disposal plant of the gravity system has been fixed at plus 8.

The design of the system has been based upon a minimum velocity of 2.5 feet per second when running one-half full, except in pressure siphons, where the minimum velocity for present flow has been fixed as 2 feet per second, which will increase with the population to an ultimate velocity of 8 feet per second.

The general design provides for carrying most of the sewage collected north of the Menomonee and Milwaukee Rivers and from the City of Wauwatosa by a dual system to the foot of Erie Street, where it is carried to the disposal plant through a double inverted siphon built under the harbor entrance.

All the sewage collected in West Allis and south of the Menomonee River is carried by a sual system to the foot of Park Street, from whence it is delivered to the disposal plant through a double inverted siphon built under the mouth of the Kinnickinnic River."

The two inverted siphons mentioned are now under construction and will be completed about May 1st 1917. Their location is shown on the plan of the layout of the proposed disposal plant in Figure IV.

18. PRESENT SEWERS OF THE CITY. A map of the City of Milwaukee showing the present city limits and the limits as proposed for 1950, is attached at the end of this thesis. This map shows the entire present combined system of sewers of the city and also the old system of interceptors. The latter are colored greed to bring out the contrast.

The present interceptors on the upper east side, along both sides of the Milwaukee River will be utilized in the new system. The Old Menomonee Valley Intercepting sewer however cannot be used. When this latter sewer was being cleaned, previous to starting experiments upon the sewage flowing from it, it gave and opportunity for an inspection of the sewer. It was found to be settled out of grade as much as two feet in places and very badly distorted. This sewer is also designed to admit river water, which is not desired in the new system. A new siphon would have to be constructed at Muskego Ave., as the old one is in very bad condition and could not be used. After considering these various faults it was decided to abandon the use of this sewer and construct an entirely new one to serve the purpose.

19. GENERAL LAYOUT OF THE NEW SYSTEM OF SEWERS. A plan showing the general layout of the new system of intercepting sewers has been platted on the map mentioned, showing the entire system as it is now planned and the probable future extensions up to 1950. The sewers that have already been completed, those under construction, the sewers for which contracts were let in 1917, and the proposed immediate and probably future extensions, have all been indicated upon this plan.

The system of sewers as before stated is a dual system serving the high and low level areas. Practically all of the sewage from the territory lying north of the Menomonee and west of the Milwaukee Rivers is carried by the system of high and low level sewers to the foot of Fowler Street and thence under the Milwaukee River in a double chamber inverted pressure siphon to Broadway and Detroit St., here the sewage from the territory on the east side of the river joins it and together through the double sewer on Broadway and Erie Streets the sewage reaches the foot of Erie St., from where it passes under the river again, to the disposal plant on the Island. The sewage from the entire south side is collected by the dual system and delivered at the foot of Park Street through a double sewer, from whence it passes under the Kinnickinnic River in a double chamber inverted siphon to the disposal plant.

The high level sewage from the west side flows through a cast iron pressure pipe from Fifth St., and Clybourn to Detroit and Broadway; the East side high level enters a pressure pipe at Mason St., and Broadway; and the south side high level sewer is a pressure section from Scott and Hanover St., to the drip shaft at Park St.

The Menomonee Valley low level Sewer has for convenience, been divided into three sections. Section No. 2, with which the remainder of this thesis is to deal, begins at Twenty-Fifth and Greves St., and extends to First Ave., and So., Canal St., including the branch on Muskego Ave. Section No. 1 extends from the end of Section No. 2. to the Park St., Drop shaft. Both of these sections are at present under construction. Section No. 3. is the section on South Pierce St., extending to 27th Street.

CHAPTER V.

FINANCES.

20. ORIGINAL FUND. The law passed by the legislature in 1913 creating the Sewerage Commission contained a clause giving the city the right to levy a special one mill tax upon all the taxable property in the city. The money from this tax was to be turned over to the Sewerage Commission as a fund to be used in carrying out their proposed projects. At that time and at present this tax amounts to about $500,000.00 annually.

This amount was ample for carrying out the work in 1913 and 1914 when most of the work consisted of experiments and planning but in 1915 when actual construction of the intercepting sewers was started the commission found itself greatly hampered by insufficient funds to properly prosecute the work. It could let but one contract in the year 1915 for construction work and at this rate it would require fifteen years, or until 1930, to complete so much of the intercepting sewers and of the sewage disposal plant as is estimated as necessary to meet the requirements of the City at that time.

21. PRESENT FUND. This fact was brought to the notice of the General Assembly and accordingly in July 1915, it passed a Bill amending the original Act of 1913, so as to grant to the Common Council the right to issue, in addition to the one mill tax, bonds not to exceed two million dollars in any one year, such bond issue to be used for no other purpose than as provided in the original Act.

This Bill carried with it the right of referendum within thirty days after the Council should pass the resolution authorizing the bond issue; by filing a petition in the office of the city clerk signed by not less than fifteen per cent in number of voters who voted in the city at the last general state election, the question of issuing bonds would have to be submitted to a vote of the people. The questions of issuing all other bonds by the city have to be submitted to the vote of the people.

In 1915 the question of a bond issue for carrying out the work of the sewerage commission was submitted to the vote of the people and the question carried by a large majority. Accordingly the Common Council authorized the sale of bonds to the amount of $1,500,000.00 annually, which, with the $500,000.00 special tax, gives the commission a fund of $2,000,000.00 a year with which to carry out their work.

It was estimated that the entire system of sewers and the sewage disposal works would cost $7,116,707.37. This estimate was made in 1915 and would not be a close figure for the actual cost, because construction prices have increased a great deal in the past two years.

P A R T IV.

CHAPTER I.

SECTION NUMBER TWO OF THE MENOMONEE VALLEY LOW LEVEL INTERCEPTING SEWER.

1. LOCATION. There were but very few conditions governing the location of Section No. 2. of the Menomonee Valley Intercepting Sewer, so there was very little trouble in choosing a final line. The largest amount of sewage to be cared for was that emptying into the river at the foot of 25th Street, and as first considered the plan was to build a siphon directly across the river from the foot of 25th Street, to South Canal St, where the mainsewer was obviously to be located. This plan was abandoned and the present plan, which is shown on the map of sewers attached at the back of this thesis, was adopted.

Had the siphon been placed at 25th St, it would have been very much more expensive to construct. The head of navigation is between 25 and 26th Street which would have meant, placing the siphon 20 or 25 feet deeper than where is is now to be located. Besides this there would have to have been built, a crossing through the river at South Canal St, at some future time to take care of the sewage accumulating from the territory lying south of Park Hill Avenue and West of 27th Street. With the siphon located where it is now it will serve this purpose as well as the flow at 25th and Greves St.

As finally decided upon, the line is to extend from the foot of 25th and Greves St, up Greves to 27th Street, thence under the C. M. & St. P. Ry. Co's. tracks and across private right of way to 27th St. and South Canal, thence easterly along South Canal St, crossing the river, to First Avenue and South Canal where it connects with Section No. 1. of the Menomonee Low Level Sewer. A branch line extends North from South Canal St. on Muskego Avenue. It crosses the river on Muskego Avenue, thence up 13th St, to St. Paul Avenue, thence up St. Paul Avenue to the alley just west of Eight St, south on this alley to Hinman Place, east on Hinman Place to Eight St. Another branch on North Canal Street connects with this line at 13th Street and runs west as far as 17th.

2. TOPOGRAPHICAL AND UNDERGROUND DATA. After the line of the sewer had been determined upon the first thing to be done was to make a survey of the streets through which the sewers were to pass. All the surface and underground structures, which might in any way influence the location and construction of the sewers, were located. The party making these surveys generally consisted of four men; an instrumentman, two rodmen, and a laborer. Every manhole and water shut off box, curbings, walks, hydrants etc, were located, with reference to street lines in most cases. All manholes were opened and if it was a sewer, the elevation of the flow line, direction of flow and the size of the sewer was determined; if it was an electric conduit manhole, the number of conduits entering, their direction and their depth below the surface was recorded, and a note made as to whether they were the Electric Co, Telephone, or Fire & Police System of conduits.

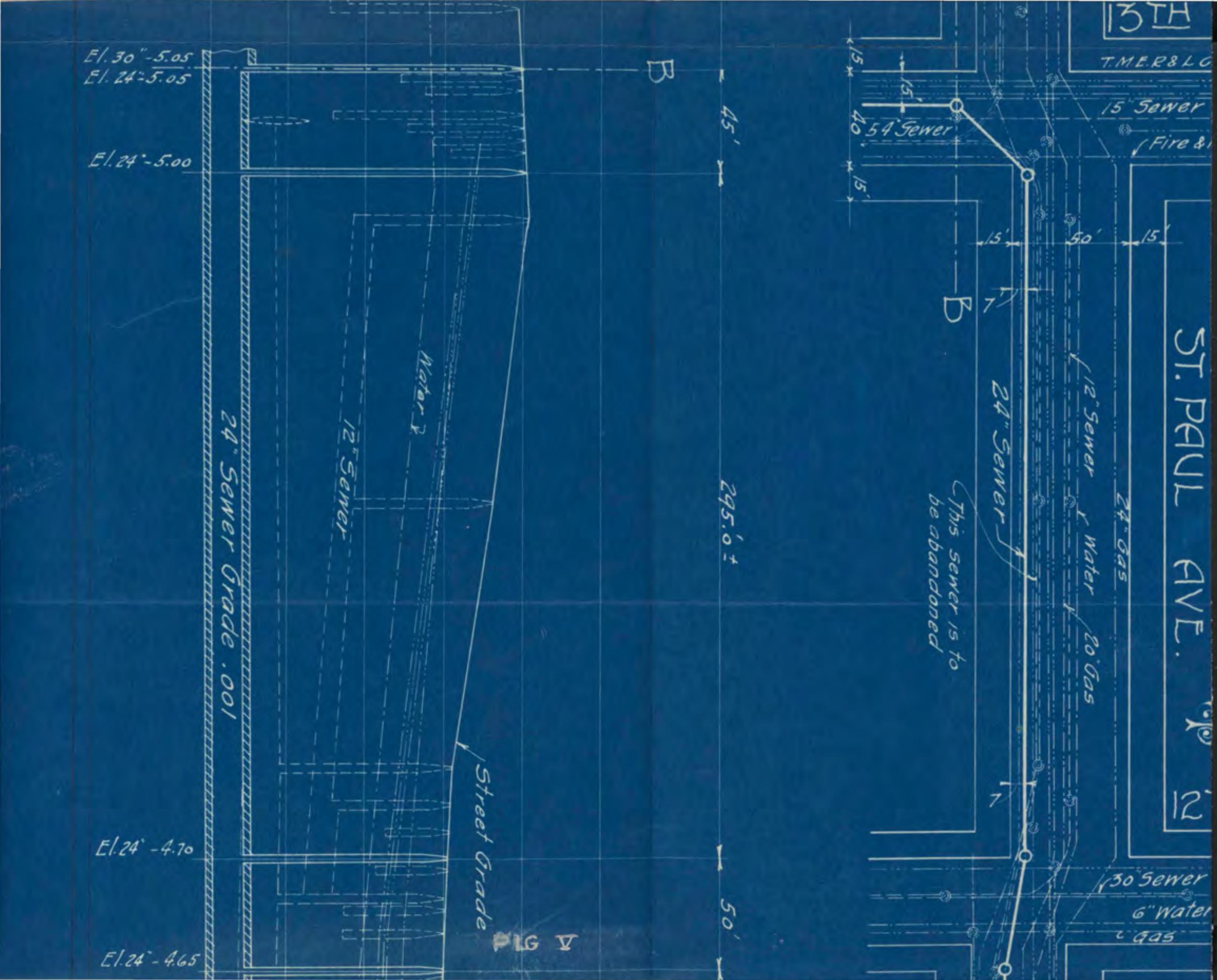
3. PLOTTING DATA. The information obtained in the field was plotted on detailed drawings of the streets made from the city maps, together with any other information concerning underground structures, which could be obtained from the records of the public service companies owning them. All water pipes were located from the water department's records and the gas mains from the Gas Company's records. At times the measurements taken in the field did not correspond with the dimensions on the city maps, but in most cases the discrepancies were not great. The city maps were assumed to be correct and the data plotted accordingly. This assumption would affect the grade very little one way or the other and as the work done was to be paid for according to actual completed measurements, there was no trouble to be expected from making such an assumption.

The surveys of South Canal Street were very simple, because there are very few underground structures in this street, but considerable care had to be used in making the surveys for North Canal St, St. Paul Avenue and Muskego Avenue and 13th St, as these streets are litterally undermined by service structures.

Figure V. is a blue print of a part of the detail drawing of St. Paul Avenue, it shows the way the survey data is plotted and the method of indicating the line and profile of the new sewer.

4. TEST BORINGS. In order to determine the kind of material that would be expected to be encountered in the new construction work, test borings were made along the proposed line on South Canal Street. There were six borings made at intervals of approximately 1300 feet. The one at the east end was carried to an elevation of minus 78.00, the one at the west end to minus 35.00, and the intermediate holes to about minus 15.00. The location and cross sections of these holes showing the material encountered was plotted on the "General Layout" drawing. When the borings were being made, each hole was numbered and as the materials changed, a sample was taken and placed in a bottle and the bottle sealed and numbered to correspond with the number of the test hole. On the label was a record of the depth at which the material was encountered and where it ended. By this method the contractor bidding on the work could easily see what kind of ground he might expect in the construction work. The drawing gave him a plat of the borings and the bottle an exact sample of the material in its natural state.

There were no borings made except on South Canal Street, where the main sewer is located. The average boring showed filled


El. 30"-5.05
El. 24"-5.05
El. 24"-5.00
El. 24" -4.70
El. 24" - 4.65
24" Sewer Grade .001
12" Sewer
Water
Street Grade
B
45'
245.0'±
50'
13TH
T.M.E.R.&L.C
15" Sewer
Fire &
54" Sewer
15'
40'
50'
7'
24" Sewer
This sewer is to be abandoned
12" Sewer
Water
20" Gas
24" Gas
ST. PAUL AVE.
12
30" Sewer
6" Water
Gas
FIG V

material, cinders, gravel and clay, for the first ten feet, then about five feet of fairly dray grayish marsh clay and the next five feet was mixed sand and a blackish sandy marsh clay, rather wet.

CHAPTER II.

RUN OFF.

5. GENERAL DETERMINATION. In designing the system of intercetping sewers the run-off to the sewers has been divided into: Domestic, Commercial and Industrial.

Domestic sewage is considered as all household wastes produced by ordinary dwelling, apartment buildings and boarding houses, as well as small hotels, hospitals, stores and shops, laundries, dye works, milk depots, and all other miscellaneous establishments lying in the Domestic Areas.

Commercial sewage includes all that produced within the commercial areas of the City, and consists of wastes from office buildings, hotels, saloons and restaurants, retail stores and shops, printing plants and living apartments.

Industrial sewage includes all sewage produced by manufacturing plants, machine shops, structural iron works, foundries, breweries, tanneries etc., including both wastes from manufacturing processes and toilet and wash wastes, as well as domestic sewage produced by dwellings within the industrial areas.

"Ground Water" and "Storm Water" have also been taken into consideration in the design.

The amount of sewage contributed under each of these headings is calculated on a basis of area, except in the case of domestic, where the population is the determining factor. The problem of computing the run-off therefore may be resolved into two parts. First the determination of the extent of area and the population served by the interceptors, and second, determination of the amount of run-off contributed per unit of area and per unit of population.

Railroad Yards and Public Parks are considered as non-run-off producing.

6. AREA TO BE SERVED. The area to be served by section No. 2. of the Menomonee Valley Intercepting Sewer in 1950 is shown colored a light orange on the large sewer map. This area at present contains about 10 acres of domestic area between 13th and 7th Streets, north of St. Paul Avenue, with a population of about 60, all the rest however consists of commercial and industrial areas, except that occupied by the National Soldiers Home. In 1950 as proposed, there will be no domestic area to be sewed, and the entire area except the Soldiers Home will be industrial. The total area of this section is about 1710 acres of which at the present time 710 acres are parks etc, considered non-run-off producing area. This condition will undoubtedly be the same in 1950. From these facts it is easily seen that it is not necessary to provide for any domestic

or commercial run-off in section No. 2 of the Menomonee Valley Low Level Intercepting Sewer, but in order to give some idea as to how the amount of this run-off is determined, a bried discussion of the method used will be given.

7. DOMESTIC RUN-OFF. The run-off classified as domestic is derived from the city water supply, as it is evident that most of the domestic water supply is returned to the sewers, the only loss being water used for lawn sprinkling purposes.

It was found by analysis of the Water Department's reports that the average per capita commercial consumption for 1913 based on a population of 450,000 was 4.5 gallons per day. This is actual "commercial" as defined in this thesis. The Water Department classifies the consumption as Industrial and Commercial. The latter however includes both "Domestic" and "Commercial" as they have been defined. It was therefore necessary to make the analysis mentioned in order to separate their Commercial consumption into our Domestic and Commercial.

The average per capita commercial consumption was 33.36 gallons. Deduct from this, 4.5 gallons and add 1.76 gallons, found to be the per capita consumption of greenhouses, shops, laundries etc, in domestic districts, and we have 30.62 gallons as the average domestic consumption of the city.

While this gives the average rate of run-off very satisfactory, there were no records available to show when the maximum rates of run-off took place. In order to determine this, sewer gaugings were made in sewers draining exclusive resident districts, and serving a combined population of 180,000. at first these gaugings were made by hook gauge and current meter but the results did not prove entirely satisfactory, so a Bristol self recording automatic gauge was resorted to and the results obtained were very satisfactory. The guagings extended over a period of about seven months.

These gaugings gave the average minimum, average maximum, average average, and the average Monday maximum rate of flow in gallons per capita per day. The figures included both ground water and Industrial Water but the latter was calculated, and deducted.

A detailed analysis of these guagings are given in the Sewerage Commissions Annual Report for 1915. From this analysis it was finally decided to establish the average per capita flow as 50 gallons, and the maximum flow as 125 gallons per capita.

8. COMMERCIAL RUN-OFF. To arrive at an estimate of Commercial run-off it was assumed that it would practically equal the metered water consumption, and an investigation of the water consumption was accordingly made of three representative downtown blocks, one containing a large department store one a large hotel and the other a large office building. These blocks also contain various retail shops, restaurants and saloons typical of the Commercial district.

By use of Insurance Maps the actual floor space in these blocks was determined and from the Water Department's records, the actual amount of water used was determined. The ratios of the maximum rates to the average rates were found from meter readings over a period of two full days. Using these figures we found that the Average daily rate of consumption was 381 gallons per 1000 square feet of floor space and the average Maximum 618 gallons.

The ratio of building area to total area, including streets and alleys for the entire commercial area of the East and West Sides was calculated from the Atlas in the City Engineers Department to be 3:5, and the average height of buildings was found to be 1.78 stories. Reducing the rate of flow to a unit per acre we have 381 x 1.78 x 43.56 x 3/5=17700 gals., per acre per day daily rate and 29,800 gals. as the maximum rate.

For purposes of design it was assumed that all the water used in the districts reached the sewers. That this is justified was established by the check sewer guagings made.

It is not reasonable to expect that the run-off per unit of floor space will be increased in 1950, but there is no doubt that the buildings will average a greater height and the run-off per acre will thus be increased.

It is assumed that the buildings will increase in height in proportion to the increase in population. From this we find that the average height will be 3.75 stories. This gives a daily rate of 37,400 gals. and a maximum rate of 60540 gals. per acre per day.

9. INDUSTRIAL RUN-OFF. It is the Industrial run-off that governs the design of the Menomonee Valley Low Level Intercepting sewer, as it is calculated that all area it is to serve up to 1950 will be industrial area.

From the water departments records of industrial consumption, after deducting our "Commercial" classification and the water carried away in locomotive boilers we found a total consumption of 758,800,000 cubic feet purely "Industrial". This gives a per capita per day consumption of 36.2 gallons, or 9,350 gallons average per acre per day considering the present industrial area as 1666 acres.

The water obtained from private sources is considerable and at first thought it might seem to increase the run-off to be expected, but this is not true as an analysis will show.

A list of twelve of the largest industrial plants of the city show a total consumption of 14,141,000 gallons per day, supplied from private sources. A considerable part of this amount, however, is made up of cooling water, condenser water and uncontaminated water generally, that can be discharged directly into the river, especially since all the plants are conveniently located for this purpose. From reports of the various concerns we find this amount to be about 10,346,000 gallons per day, including 360,000 gallons which are sent out in beer by the three large breweries. This would leave 3,795,000 gallons per day from private sources that would reach the sewers.

Within the industrial area there is a population of about 15 per acre, which at 31 gallons per day would contribute 776,000 gallons of run-off per day, making a total flow of 4,571,000 gallons.

From an estimate made by the Board of Stationary Engineers, the water used for steam purposes in plants running non-condensing engines and having boiler plants of less than 1000 horse power, (totaling 150,000 horse power) amounts to 3,600,000 gallons. The larger plants are run condensing, but in most cases, the condensed steam is rejected with the cooling water. The Blatz Brewing Company with 3,400 horsepower stated that 91,700 gallons of water are used daily for boiler feed, and there are at least 10 firms with equal or greater horse power which would account for 900,000 gallons more. This gives us 4,500,000 gallons used for steam purposes which offsets the amount from private sources not accounted for above. The true "Industrial" consumption of city water has accordingly been accepted as the run-off to sewers in the Industrial area.

It was not possible to obtain an average and maximum flow either by sewer guagings or meter readings, but the maximum flow has been assumed to be twice the average which if wrong will err on the side of safety. The quantities of Industrial run-off therefore as estimated for 1914, were 9350 gallons per acre average flow and 18,700 gallons maximum flow.

Assuming that the Industrial consumption per capita for 1950 would not change materially from the 36.2 gallons per capita already determined, we find, using a population of 862,000 in 1950 and an Industrial area of 3762 acres, the run-off to be

$$\frac{862000 \times 36.2}{3762} = 8,300 \text{ gallons average}$$

and 16,600 gallons maximum as the Industrial flow for 1950.

For computing the run-off from industrial areas a sliding scale was used, having a high rate of run-off from small areas and a continuously decreasing rate as the area increased, the value of 16300 gallons per acre per day being taken as the limiting amount as the average maximum for the whole city.

10. GROUND WATER. From gaugings of the sewers in various districts it was found that the average maximum ground water to be expected amounted to about 1620 gallons per acre per day. This is on the safe side because the minimum flow in the sewers occurring between 2:00 and 5:00 P.M. was all considered to be ground water and this evidently containes some sewage.

11. STORM WATER. As Milwaukee is sewered upon the "Combined plan, storm water is mixed with the sewage in time of rains. The volume of water flowing in the sewers during storms is often increased to 50 or 60 times the ordinary dry weather flow. The construction of intercepting sewers large enough to carry this volume to the disposal plant, to say nothing of the construction of a plant sufficient to care for it, would be so expensive as to be out of the question.

Taking all the storm water to the disposal plant, however, is neither necessary nor desirable. In fact were it possible to separate the flow, the storm water could all be discharged into the rivers without serious damage. As this is not possible, it becomes necessary to construct intercepting devices, that will reject all, or the greater part, of the flow when it rises above a certain maximum.

The intercepting sewer must in consequence have sufficient capacity to care for this maximum and the maximum must be established with the idea in mind of obtaining the greatest efficienty from the interecepting sewers.

Engineers have long held to the veiw, and it has been proven by tests conducted by the Sewerage Commission, that the first flush of storm water from the streets is quite foul and that there is a dilution of foulness as the storm continues. It must be borne in mind however, that probably much of the foulness of the water is due to organic matter of vegetable origin that would not be especially harmful to discharge directly into the rivers.

During light rains of which many occur throughout the year, a considerable amount of fairly strong sewage would be discharged into the rivers were the capacity of the sewers too restricted; and likewise, considerable sewage is collected on the sides of the sewers during the ordinary flow, which is washed off by the increase flow caused by the storm water. This latter is especially undesirable for discharge into the rivers. It is recognized that in the end the amount of storm water for which it is advisable to provide can only be determined more or less arbitrarily by exercise of judgement, but an analysis of conditions has aided in arriving at a decision.

The sewers are given a capacity to last until 1950. Hence, upon construction there will be considerable surplus capacity available for storm water that will decrease with time. The sewers are designed to carry the maximum flow of the day. As the rains occur at any time during the 24 hours, it is believed that for the greater part of the time there will be a capacity in the sewer available to carry storm water.

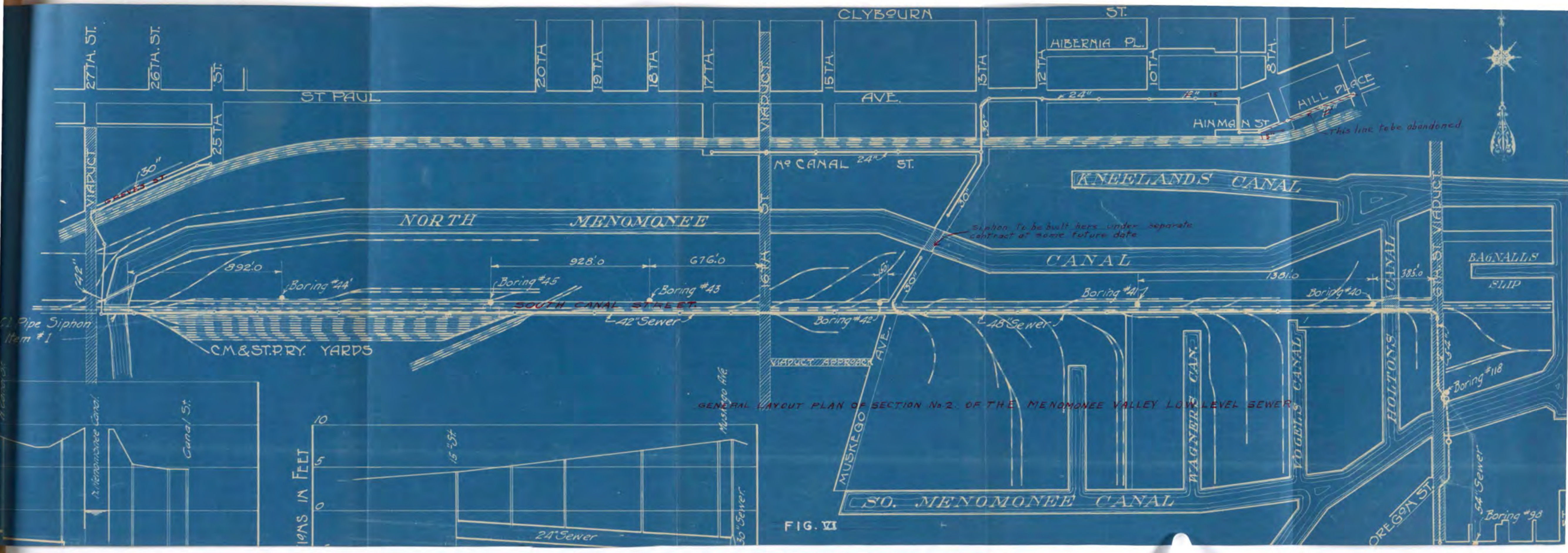
This surplus capacity which can be used for storm water, except during the period of maximum flow, varies of course with the territory for which the intercepting sewer is designed. Hence the question of storm water is taken up for each class of district.

The estimated average rate of run-off in the Commercial district is 37,500 gallons, be acre per day and the daily maximum is 60000 gallons per acre per day . The sewers being designed for the latter figure there would be a capacity of 22500 gallons per acre per day available for storm water flows. This is equivalent to 0.0347 cu. ft. per second per acre. Therefore on the average, storms of an intensity not greater than .0347 in. per hr. will be accomodated in the Commercial districts.

This amount is thought to be ample to cover the first flush of the storm, and as determined by analysis, an increased efficiency of 1% would involve an increased cost of 15%, no additional provision for storm water from this district, has been provided for.

For the Industrial District there is provided a maximum rate of 16800 gallons per acre per day and an average of 8,400 gallons per acre per day, giving a capacity of 8400 gallons per day available for storm water flow. This figure however holds only for large areas. As stated before the industrial run-off has been calculated from a curve using a sliding scale of run-off increasing as the area decreases. The largest Industrial area drained by any one interceptor is 1200 acres. The units used for this area taken from the curve mentioned is 20000 gallons per acre per day maximum and 10000 gallons per acre per day average, giving a capacity for storm water of 10000 gallons per acre per day equivalent to 0.017 cu. ft. per second. Therefore the Industrial interceptors will accomodate a rain-fall equivalent to 0.017 inches per hour.

It is believed that provisions for.01 of an inch rainfall per hour would amply provide for the first flush of any storm, which is known to be particularly foul, and as the amount of precipitation falling at this rate, or less, as determined from a curve plotted from the U. S. Weather Department's records for 1911, 12, 13, and 14, represents an average of 275 hours rainfall per year of the 572 hours total rainfall, the interceptors would be closed only about 300 hours per year, or 3.4% of the total time.


CLYBOURN ST.
27TH. ST.
26TH. ST.
ST.
20TH
19TH
18TH
17TH.
VIADUCT
15TH.
13TH
12TH
10TH
8TH.
HIBERNIA PL.
ST PAUL AVE.
HINMAN ST
HILL PLACE
This line to be abandoned.
25TH
30"
24"
Mc CANAL ST.
KNEELANDS CANAL
NORTH MENOMONEE CANAL
Siphon to be built here under separate contract at some future date
BAGNALLS SLIP
16TH ST.
6TH. ST. VIADUCT
892.0
928.0
676.0
1381.0
385.0
Boring #44
Boring #45
Boring #43
Boring #42
Boring #41
Boring #40
Boring #118
Boring #98
SOUTH CANAL STREET
42" Sewer
48" Sewer
54" Sewer
C.I. Pipe Siphon Item #1
C.M.&ST.P.RY. YARDS
VIADUCT APPROACH
MUSKEGO AVE.
GENERAL LAYOUT PLAN OF SECTION No.2 OF THE MENOMONEE VALLEY LOW LEVEL SEWER
WAGNERS CAN.
VOGELS CANAL
HOLTONS CANAL
OREGON ST.
SO. MENOMONEE CANAL
N. Menomonee Canal
Canal St.
15th St.
Muskego Av.
30" Sewer
24" Sewer
10
5
0
IONS IN FEET
FIG. VI

The estimated density of the population within the city limits in 1950 is 40 per acre. The maximum domestic flow being 125 gallons and the average flow 50 gallons per capita, gives a capacity of 40 x 75 or 3000 gallons per acre for storm water in the Domestic district sewers. This is equivalent to .0045 cubic feet per second or approximately .005 inches of rainfall per hour. Since as stated above it is deemed advisable for .01 of an inch an addition of .005 of an inch of rainfall has been provided for in the design of the domestic sewers. This is equivalent to 3200 gallons per acre per day or a total maximum of 8200 gallons per acre per day. The latter figure is the one for which the sewers were designed.

CHAPTER III.

DESIGN.

12. ALIGNMENT. The alignment of the Menomonee Valley Sewer has already been discussed in a preceding article. Figure VI showing the entire line is inserted here for convenience and for reference purposes. The line of sewers as they are being built follow this plan except at 8th Street and Hill Place where a change has been made and is indicated in red on the print.

13. GRADE, SIZE, and VELOCITY. At 25th and Greves Street there is a large junction chamber for three sewers with an outlet to the river. It was the elevation of this outlet that fixed the end elevation of the new sewer that was to intercept its flow. The elevation of the outlet is about minus 1.50 so with a 30" sewer, which is the size used, flowing half full, it was necessary to establish the flow line elevation at minus 3.58 to properly intercept the flow. The other governing elevation of the design is that at which the low level sewage reaches Jones Island which has been established at minus 16.00. This gave a total available drop of 12.42 feet from the Island to 25th and Greves St, 4.89 feet of which was used up to 1st Avenue and South Canal Street leaving 7.53 feet available for the design of Section No. 2 of the Menomonee Valley Low Level Sewer.

In order to fulfill the conditions established for velocity in pressure siphon it was necessary to use 1.03 feet of the available head in the design of the Menomonee River Siphon at 27th Street leaving only 6.50 feet for the line of sewers. At Muskego Avenue and South Canal St. in order to intercept the flow from the north side of the Canal from a system of sewers of the most economical design with a siphon across the canal it was necessary to establish the flow line elevation of the main intercepter as minus 9.69 at this point.

Using these limiting conditions and Chézy's formula $V = C\sqrt{R.S.}$ with "Kutters" Value of c with n equal .013 the system of sewers was designed. The limiting value of V was established as 2.5 feet per second for the 1950 flow and all curves are of 50

TABLE No. 2

TABLE OF FIGURES AND QUANTITIES USED IN DESIGNING SECTION No.2 OF THE MENOMONEE VALLEY LOW LEVEL INTERCEPTING SEWER

Location of Sewer			Stra't	Drop	Curve	Drop	Total	"Q"	Intercepted	Size	Vel.	Grade	Flow	
Street	From Street	To Street	Length Ft.	Ft.	Length Ft.	Ft.	Drop Ft.	Cu.Ft. Per Sec	At	Dia. In.	Ft.per Sec.	Per Ft.	Parts Full	Dpth Ft.
Greeves	25th.	27th.	748	.66	48	.076	.735	6.8	25th. and Greeves St	30	2.5	.00088	0.5	1.25
27th.	Greeves	So.Canal	516	.285	78	.124	.409	20.4	27th&Greeves " So. Canl	42	2.5	.00055	0.7	2.45
Siphon on	South Canal Str.		210	1.03			1.03	"	"	30	4.16		1.0	2.50
So.Canal	Siphon	Muskego	3922	2.17			2.17	"	"	42	2.5	.00055	0.7	2.45
"	Muskego	1st. Ave	3150	1.35	111	.178	1.53	29.7	So.Canal & Muskego Av	48	2.5	.00046	0.8	3.20
Muskego	So.Canl	No.Canal	535	2.58	134	.34	2.*92	9.3	No.Canal & Muskego Av	30	2.5	.0009	0.7	1.75
No.Canal	17th.	Muskego	1690	1.91			1.91	4.6	No.Canal & 15th & 17th	24	2.5	.0012	0.6	1.20
13th.	St.Paul	No.Canal	280	0.22			0.22	4.7	St.Paul Av & 13th.	30	2.5	.0008	0.4	1.00
St.Paul	10th	13th	995	1.01			1.01	4.7	St.Paul at 10th St.	24	2.5	.001	0.5	1.00
St.Paul Alley & Hinman	10th.	8th.	975	1.56		.20	1.76	2.3	8th.St. & Hinman Pl.	15	2.5	.0016	0.8	0.90

* Includes 2.1 feet drop through the Muskego Avenue Siphon.

Note-- A minimum velocity of 2.5 feet per second has been established.
All curves are of a 50 feet radius, and have .0016 added to the regular grade per foot of the sewer.

feet radius with a grade of .0016 added to the regular grade. With the formula Q=A V. using the V. from the above formula and the Q determined from the run-off quantities established the sizes of the various sewers were calculated. All the sewers areof circular sections, and the theoretical hydraulic gradient was assumed to be the inside top of the pipes. Accordingly when the sizes changed these top elevations remained the same, and the flow lines were dropped an amount equal to the difference in the sizes of the pipes. All laterals and stub connections were made with the haunches at the same elevation.

Table No 2 gives the values of Q, the length and drop, curve length and drop, total drop, size, velocity, grade and parts full that the sewers will be running;

14. TYPE OF SEWERS. The commission has adopted cast iron pipe for all pressure sections, concrete for sewers of 30 inches in diameter and up, and terra cotta pipe encased in concrete for all sewers 24 inches or under in diameter.

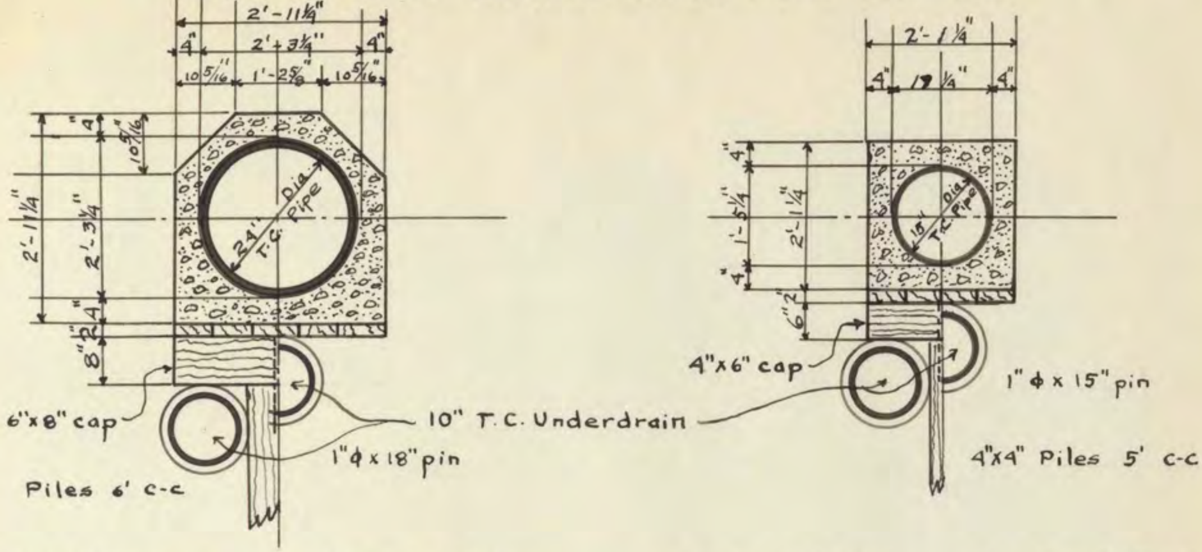
15. DESIGN OF SECTIONS OF SEWERS. The detail drawings of the 15 and 24 inch terra cotta pipe sections used are shown on Plate I and the drawings for the concrete sewers being built are shown on Plate II. Special attention is called to the fact that these drawings give details for both soft and firm earth. It is never known especially in Milwaukee just what underground conditions will be encountered but in the Menomonee Valley it is safe to expect a soft earth, a marsh clay for a foundation, as the test borings show, in most cases.

The concrete covering for the standard terra cotta pipe section is a new idea originated by Mr. Hatton chief Engineer. This is really only a protective covering and is not considered as a part of the sewer. Although the covering will undoubtedly help in making a more water tight sewer, nevertheless the pipes are supposed to be laid, and joints calked and cemented just as though no concrete were to be used. The concrete is certainly an aid in keeping the sewer to a true grade and alignment and will protect the pipe from the pick or other tools that might be used in opening up the streets, and as stated will also guard against leaks, but there is a question in the dubious mind as to whether these advantages warrant the extra cost of the concrete covering, with materials at the present prices.

In designing the sections of the concrete sewers, a combined formula using the elastic ring formula M=.0625 Wd with the "Ames" experimental value of W corrected for horizontal pressure inserted, was used. The "Ames" experiments were made to determine the loadings on sewers built in open cuts, for various values of H/B where H is the height, in feet of the backfilling over the pipe and B the width of the trench at the top of the pipe. The "Ames" experimental results did not consider any horizontal component whatever, so new values were arrived at by assumming that .30 of the load derived was the horizontal component and that .70 of the load acted vertically. This .70 of the experimental load is the W used in the elastic ring formula, with earth at 120 lbs. per cubic foot.

In using this formula the value of H in H/B was assumed to be 25 feet and all the sewers designed accordingly. It was found that the moments thus determined would hold for the sewer built at any depth down to 25 feet. That is, were the sewer built near the

SECTIONS OF TERRA-COTTA PIPE SEWERS



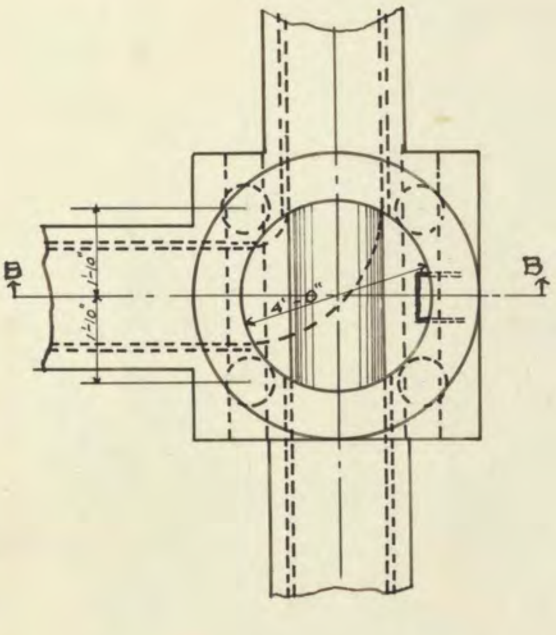
HALF SECTION	HALF SECTION	HALF SECTION	HALF SECTION
Soft Earth	Firm Earth	Soft Earth	Firm Earth

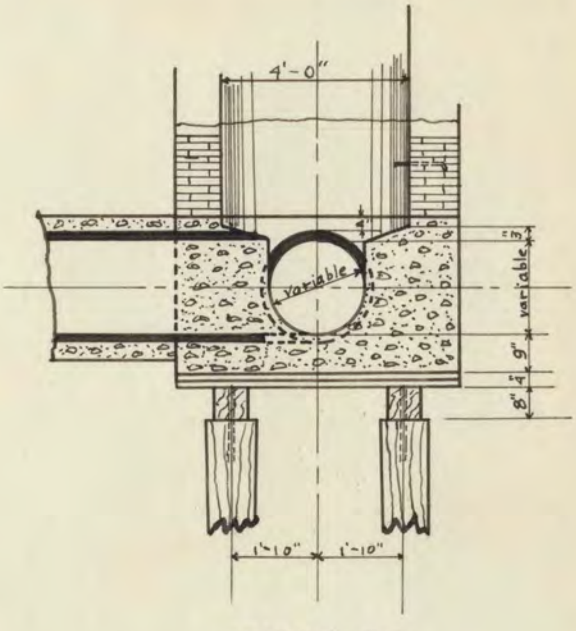
Concrete 0.142 cu.yd. per foot.
Floor 5.88' B.M. " "
Caps 1.96' B.M. " "

Concrete 0.104 cu.yd. per foot
Floor 4.21' B.M. " "
Caps 0.84' B.M. 0.' " "

24" TERRA COTTA SEWER **15" TERRA COTTA SEWER**

TYPICAL DETAIL OF MANHOLE FOR TERRA-COTTA SEWERS ON RUN AND CURVE

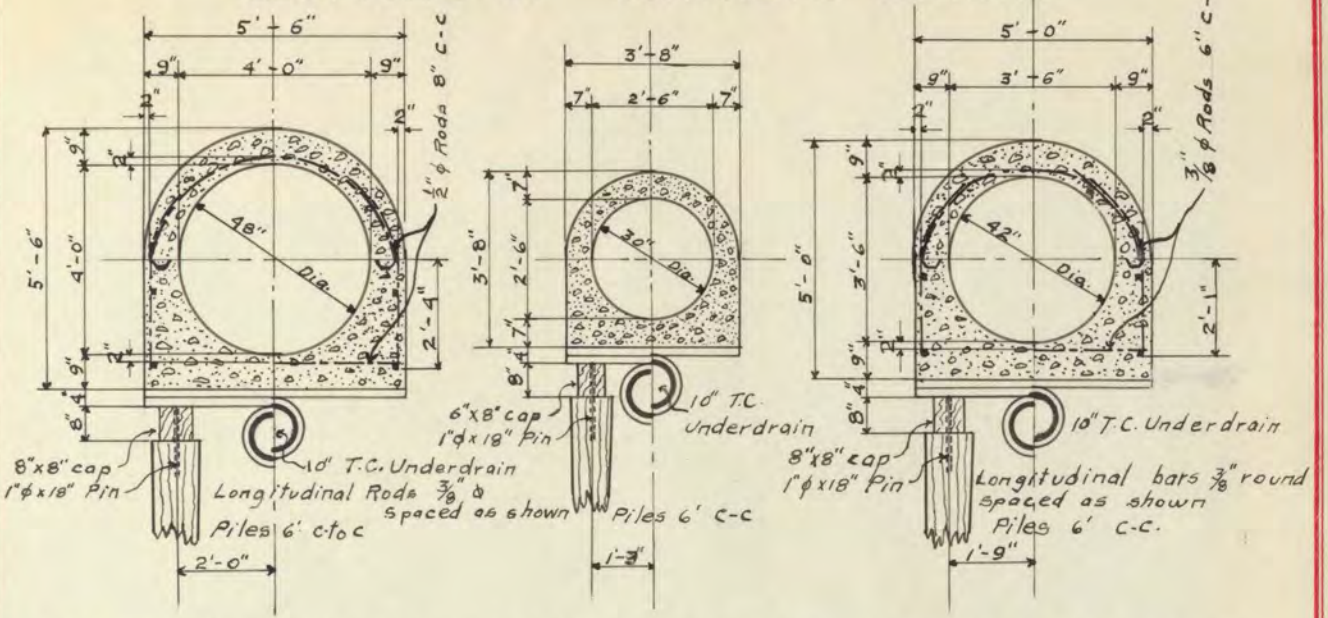




SECTION B-B

PLATE I

SECTIONS OF CONCRETE SEWERS

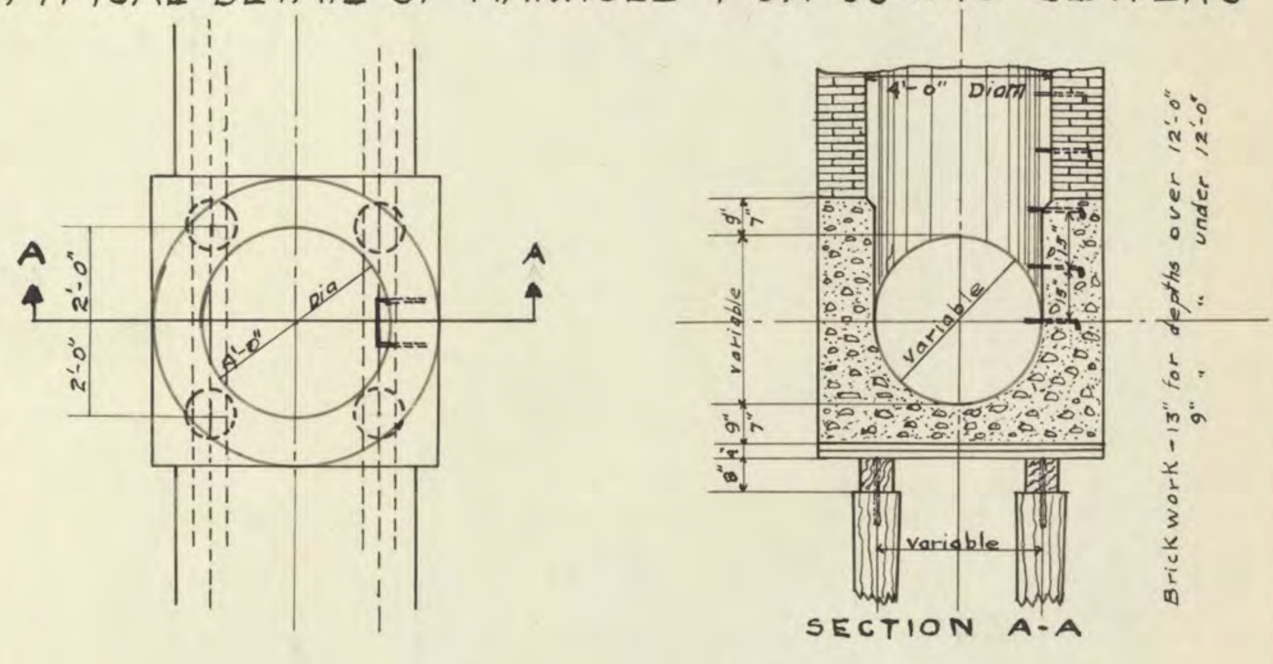


	HALF SECT. Soft Earth	HALF SECT. Firm Earth	HALF SECT. Soft Earth	HALF SECT. Firm Earth	HALF SECT. Soft Earth	HALF SECT. Firm Earth	
Concrete –	.535 c.y.	.535 c.y	.263 c.y.	.263 cy	.470 cy.	.470 cy.	Per foot
Steel –	19.5#	25.59#			13.79#	18.17#	" "
Floor –	22' B.M	11' B.M.	14.67' B.M.	7.33' B.M.	20' B.M	10' B.M	" "
Caps –	10.67 "		8.00 "		10.67 "		" "

Special Heavy 48" Sewer.

Special Heavy 42" Sewer

TYPICAL DETAIL OF MANHOLE FOR 30" TO 48" SEWERS



SECTION A-A

PLATE II

surface, the moment caused by the dead and the live load combined would be about the same as the moment in the sewer built 25 feet below the surface, and the moments of the dead and live loads would average up to this same figure were the sewer built any place between. B was always assumed to be,6 inches added to the width of the concrete sewer on either side. This is a safe assumption because the trench opened up is always wider than this, to permit the placing of bracing.

The theoretical sections required using this formula were all too small from a standpoint of practical construction, therefore an arbitrary thickness of 9 inches for 42 inch and 48 inch sewers, and of 7 inches for the 30 inches sewers was established. The nine inch assumption holds for sewers in open cut up to 60 inches in diameter.

Increasing the thickness in this way at the crown where the maximum moment occurs, throws nearly all of the stress into compression and therefore reduces the tension at the center of the intrados to a negligible quantity so that no reinforcing steel is needed, it being assumed that the concrete will carry whatever tension there is. However on account of the close proximity of railroad tracks to the 48" and 42" sewers the latter passing directly under tracks, and the very loose ground, it was assumed that some condition might arise which would cause unforseen stresses in the ring. To take care of this it was deemed advisable to place some steel in the section, so the chief engineer arbitrarily ordered the reinforcement as shown on the detail plans on Plate II.

There was really no design necessary for the cast iron pipe sections, it being assumed that class "A pipe would easily fulfill all requirements.

The siphon under the river which is of cast iron pipe is encased in concrete as a protection covering and to add weight to resist the buoyant force should the sewer ever become undermined by the water.

16. DESIGN OF MANHOLES, FRAMES AND COVERS. Typical details of standard manholes for terra cotta pipe and concrete sewers are shown on plates I and II. The details of the top three feet, frame, steps and cover are shown on plate III.

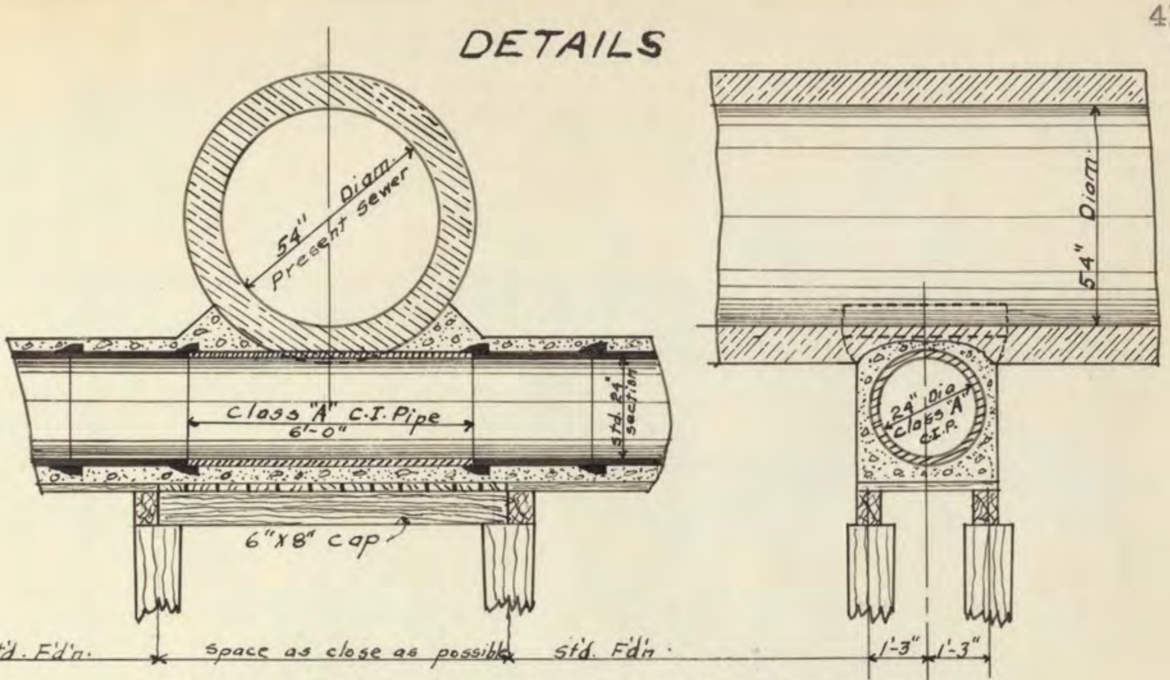
The manholes are intended to be built of brick but permission is granted, if the contractor prefers, to use concrete instead. A minimum thickness of 9 inches for walls of maholes less than 12 feet deep and 13 inches for those more than 12 feet deep has been established as a standard. The cover and frame are designed for a concentrated live load of 13000#. The steps are designed to resist erosion and are of 1" round galvanized metal spaced 15 inches center to center.

17. SPECIAL CROSSINGS. There are two special crossings required both located where the new sewers cross through or under the old Menomonee Valley Intercepter.

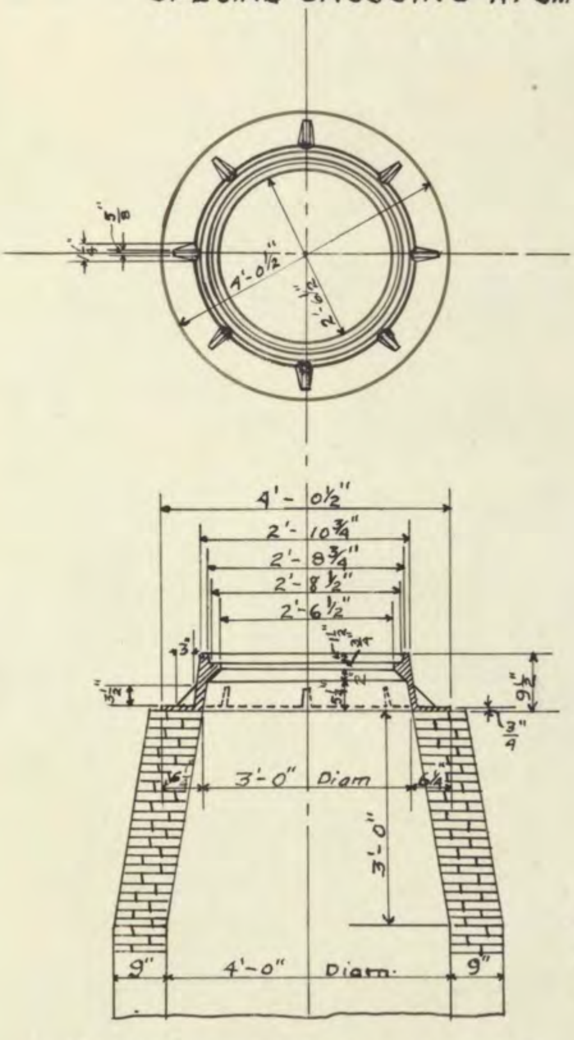
Plate III shows the detail of the crossing at 13th Street and St. Paul Avenue. It is possible that one ring of brick from the bottom of the old 54 inch sewer can be removed and the cast iron pipe put in place and concreted with out the old sewer giving way. If on opening up around the sewer, this is found impossible some other means, probably fluming will have to be resorted to.

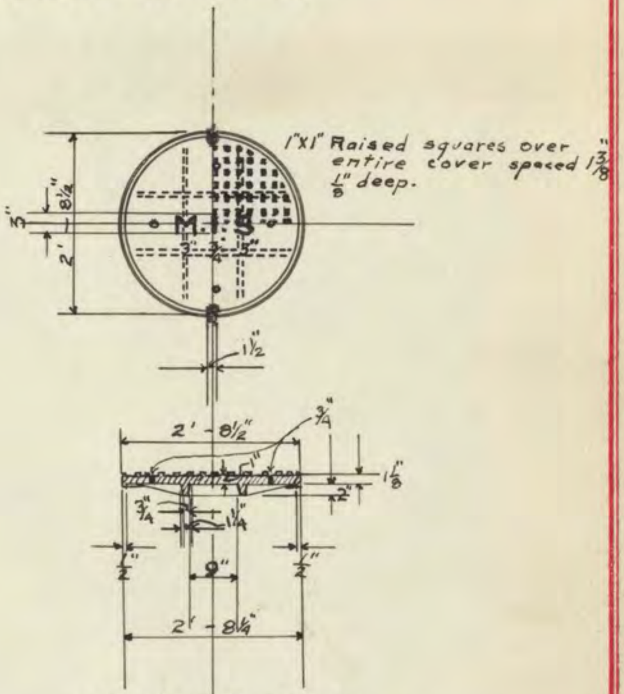
The special crossing at Muskego Avenue and South Canal Street is shown in detail on plate IV. This will be easy to construct because all the sewage can be diverted into the river before

DETAILS

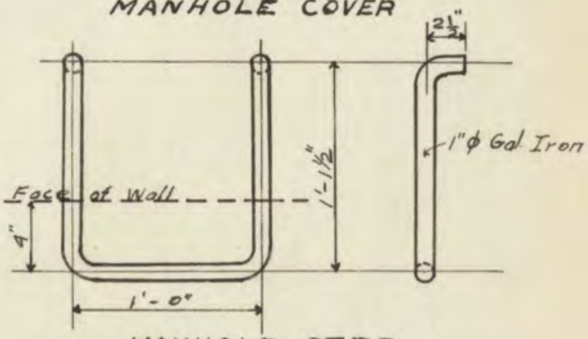


SPECIAL CROSSING AT ST. PAUL AVE. AND 13th ST





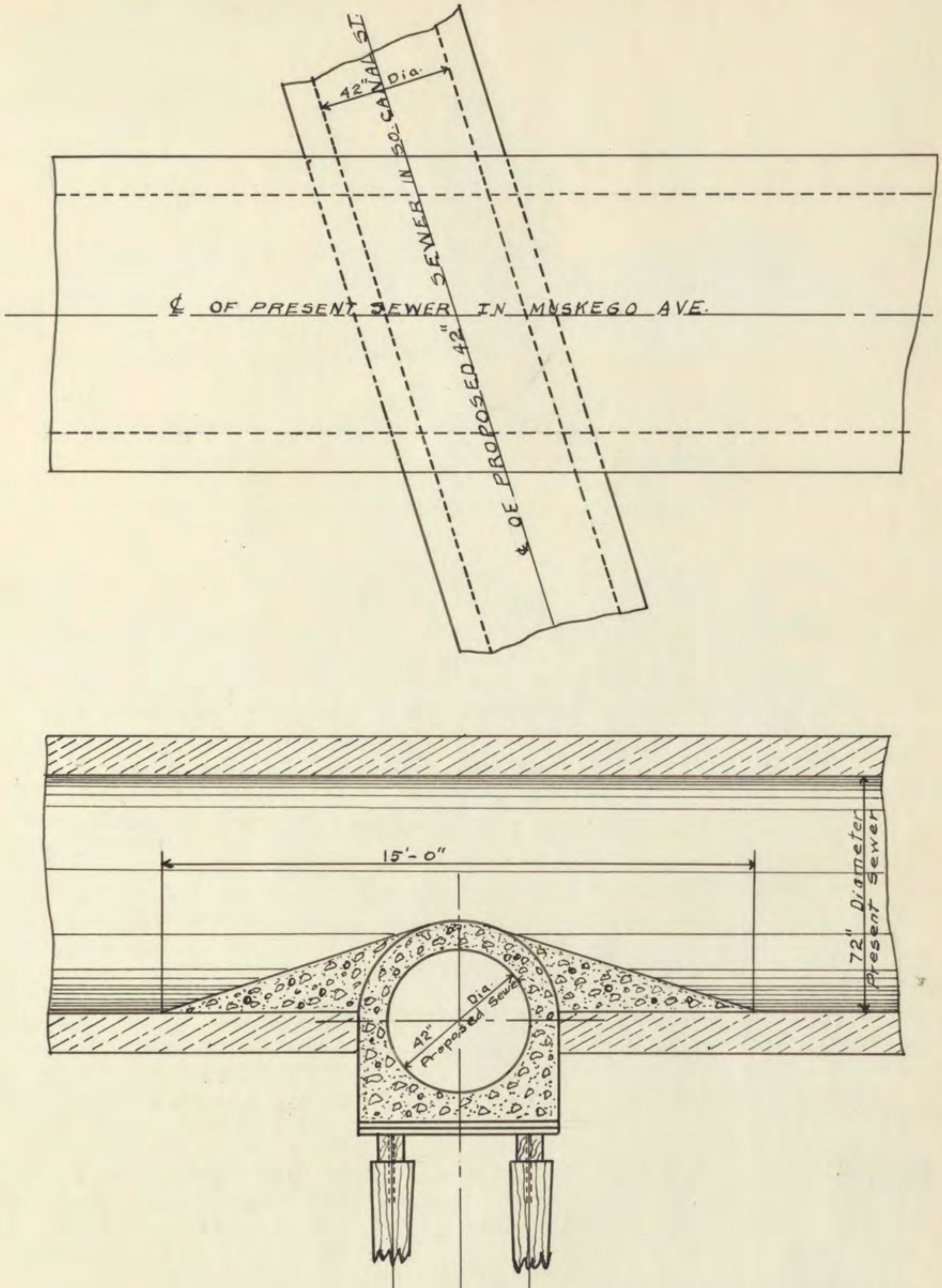
MANHOLE COVER



MANHOLE FRAME AND TOP

MANHOLE STEP

PLATE III



DETAIL OF SPECIAL CROSS'G, AT SO. CANAL AND MUSKEGO AVE.

PLATE IV

it reaches this section. The sewer will be built through after removing the old intercepter and this will then be repaired according to the plan.

CHAPTER IV.

SPECIFICATIONS.

18. UNDERDRAINS. 1. The Contractor shall remove by pumping, bailing or otherwise any water which may accumulate or be found in the trenches and other excavations made under this contract.

2. When the nature of the sub-soil is such, that, in the opinion of the Chief Engineer, under-draining is necessary to properly build the work, under-drains shall be furnished and laid of the sizes and form shown upon the plans. They shall be laid in the bottom of the trench, as near the center as practicable, with true and even grade, and led to a pump or sump well from whence the Contractor, at his own expense, will be required to remove the water continuously so long as the engineer believes it necessary to secure water-tight work. When the well is no longer necessary it shall be filled in and the section of the under-drain feeding it may then be abandoned. The Contractor will be required to keep the under-drains open, so that the water will run freely, by using rods, knotted rope, chain or some other approved device until the engineer believes such drain or such portion thereof, may no longer be necessary. Wherever the Chief Engineer orders the laying of an under-drain as aforesaid, the Contractor will be allowed the price named in the contract therefore (except in tunnel), which price must include all the materials and labor necessary to lay said drain, including the necessary excavation therefore and the cost of maintaining a free flow there through. If the Contractor fails to maintain a free flow of water through said drain at all times when the Chief Engineer may think necessary for the protection of the work no extra allowance whatever shall be made for its construction or replacement.

19. PILE FOUNDATIONS, CAPS AND FLOORING. 3. The detail plans of the work show a timber and pile foundation under every size sewer to be built in open cut, but such foundation is to be built only where ordered by the Chief Engineer, and when ordered it shall be built of the form and dimensions shown on the plans. Where the

character of the sub-grade is of sufficient stability, in the opinion of the Chief Engineer, no timber or pile foundation will be required.

4. Where timber caps are required they shall be furnished of good, sound yellow pine of the sizes shown upon the plan. They shall be attached to each pile by a steel pin one inch in diameter, and at least eighteen (18") inches long. The cap first being bored to receive the pin. The cost of furnishing and placing pin to be included in price named in contract for timber caps.

5. Where plank foundations are required, the planks shall be of good sound timber common to the local market, and shall be of the size shown upon plan. The planks shall be placed on the bottom at right angles to the axis of the sewer, or as the engineer directs, and shall have a firm and even bearing upon the caps and thoroughly spiked thereto. Their top surface shall be laid paralled with the grade of the sewer, and upon it the concrete shall be laid.

6. All piles, except those to support pipe sewers, less than eighteen (18) inches in diameter, shall be composed of straight, sound, live timber, free from cracks, shakes or rotten knots, cut from oak, spruce, pine or some other timber satisfactory to the Chief Engineer. They must be so straight that a straight line taken in any direction from the center of each end of the pile, and run the length of it, shall show that at no point is the pile over one-fourth (1/4) of its diameter, at such point out of a straight line. Each pile must show an even and gradual taper between ends. Branches and knots are to be neatly trimmed and the small end sharpened.

7. Piles shall not be less than 6 inches in diameter atnthe small ends and not less than the diameter shown in Table of Minimum Cut-off Diameters. Where cut-off, all dimensions are to be measured exclusive of the bark. The point of each pile shall be trimmed to a 4-inch square and at right angles to the axis of the pile unless otherwise ordered.

8. Table of Minimum Cut-off Diameters for piles of different lengths.

Length, feet	20	20-25	25-35	35-45
Diameter, inches.....	10	11	12	13

9. Piles are to be placed in the relative position shown upon the plans. The lengths of the piles shall be determined by the Chief Engineer during the progress of the work. The Contractor will be required to have at his disposal an assortment of lengths for immediate use when called for. The piles may be driven either with a falling or steam hammer. If a falling hammer is used its weight shall be at least two thousand (2,000) pounds, having a fall of at least fourteen (14) feet. If a steam hammer is used it shall have a total weight of about four thousand (4,000) pounds, and when operating with full blow, shall give a blow equal to thirty-eight hundred (3,800) pounds. The guides of the falling hammer shall be so arranged as to permit of being lowered to the bottom of the trench as the pile is being driven. All piles shall be driven vertically and be correctly centered. Any pile which has been injured in driving or driven out of place shall not be paid for. Unless otherwiseordered by the Chief Engineer all piles shall be driven until the last five strokes of the falling hammer, falling through a length of fourteen feet, shall not settle the pile over

three inches. If steam hammer is used, the last ten full strokes shall not settle the pile over three inches.

10. Where it becomes necessary to splice piles it shall be done by sawing off the head of the pile to be spliced squarely, driving upon it a wrought steel pipe three-eights (3/8) inch thick and one (1) inch less in diameter than the pile and eighteen (18) inches long, nine inches of which will envelope the pile to be spliced and the upper nine inches will envelope the additional pile. Such splices must be furnished and placed by the Contractor without additional cost.

11. Where the Chief Engineer orders piles to be placed to support pipe sewers less than eighteen (18) inches in diameter, they shall be composed of square timbers four inches by four inches (4" x 4"), and of such length as he may order. These timbers will be sharpened and driven by means of a heavy maul or light hammer. Such piles will be capped with a 4" x 4" yellow pine timber upon which shall be placed two-inch planks to form the foundation of the concrete enveloping the pipe.

12. The butts of all piles, when being driven, must be protected against damage from hammer, by using a metal cap of approved design. The butts must be sawed off parallel with the grade of the sewer so as to afford a full and firm seat for the cap.

13. Piles remaining in the structure as permanent construction, and any left in by order of the Chief Engineer for the safety of the work or test piles left in place, shall be paid for by the lineal foot, measured after they have been driven and cut off (except where notes upon the plans provide they shall be included in price named for the item of which they form a part). The parts of the piles cut off and wasted will not be allowed for. The price named in the contract for piles shall include the furnishing of all tools, plant, labor and machinery necessary to place them where directed by the Chief Engineer, and shall include the cutting off.

14. Caps and timber foundation, where ordered to be used by the Chief Engineer, shall be paid for at the prices named in the contract for such items (except where notes upon the plans provide they shall be included in price named for item of which they form a part).

15. They will be measured in place, and will not include any waste. The cost of furnishing and placing all pile, cap and timber foundation, as named in the contract, will include all excavation necessary to cut off the piles, or to properly place the cap and timber foundation, and all back filling of suitable material about the caps and under the timber foundation to form firm bearing therefore, also all spikes, pins or nails necessary to secure the foundation and as required by the Chief Engineer.

20. CEMENT. 16. All cement used shall be Portland cement of standard manufacture, to be approved by the Chief Engineer, of a uniform quality and shall comply with standard specifications adopted by the United States government on April 30, 1912, and known as the "United States Government Specifications for Portland Cement" published by the Bureau of Standards. It shall be tested by the Chief Engineer in compliance with the methods stipulated in said specifications.

17. Every facility for testing cement must be furnished by the contractor without additional expense, unless the Chief Engineer determines to have the tests made at the mill in which case the expense of such inspection will be borne by the Sewerage Commission. Should the cement be tested in Milwaukee the Contractor must have it delivered in his store house at least twelve days before it can be used, and the Chief Engineer be at once notified of its arrival there, and no cement must be used until it has been examined and approved by the Chief Engineer, As soon as cement has been unloaded from boats or cars it must be amply protected from dampness by storing in a water-tight building. When deposited along the line of work it must be placed upon platforms supported above ground and covered with water-tight tarpaulins.

18. All cement shall be delivered in strong cloth or canvas bags containing 94 pounds net, or in sound paper-lined barrels containing 376 pounds net. Each package shall be clearly marked with the brand and manufacturer's name. After a brand of cement has been accepted by the Chief Engineer, and the Contractor has made a contract therefor, no other brand will be permitted to be used upon the work except by special permission of the Chief Engineer. This provision is made to avoid the frequent changing of cement which may delay the work of testing, etc.

21. GRAVEL, STONE AND SAND. 19. Gravel shall be composed of clean, hard stone, freeffrom dirt, loam, mica, clay and organic matter, and shall be graded so that the smallest particles shall be retained on 1/4" openings in a rotary screen, and the largest particles shall pass through 1-1/2" openings in a rotary screen. There shall be at least one-third of the larger particles.

20. Broken stone for concrete shall be hard, sound and durable, crushed from lime stone, granite or trap rock, free from loam, clay, organic matter or objectionable quantities of dust or other materials considered undesirable by the Chief Engineer. The broken stone shall be of the same grading as above stated for gravel.

21. If permitted, by the Chief Engineer, gravel and broken stone may be mixed, the purpose of which would be to enable a misture to be made with the two, which would make a more suitable concrete.

22. The sand shall be clean and sharp, free from dirt, loam, mica and organic matter, and shall not contain more than 5 per centum by volume of clay, and no clay shall be added: 100% shall pass, when dry, a screen having 1/4" diameter holes or four meshes to the linear inch, and not more than 30% shall pass a standard No. 100 sieve.

23. Samples of sand, gravel and stone which the Contractor proposes to use shall be submitted to the engineer if so required by him, in such quantities as will enable him to conduct experiments in order to secure the best combination thereof for use in the work.

22. MORTAR AND CONCRETE. 24. All mortar, unless otherwise specified, shall be composed of one volume of cement and 2-1/2 volumes of sand. For purposes of measurement a barrel of cement shall be considered to contain 3.68 cubic feet and a bag of cement 0.92 cubic feet.

25. The ingredients must first be thoroughly mixed dry in a suitable tight box, after which the proper quantity of clean water shall be gradually added and then the materials shall be hoed or worked until a uniform mixture is secured. No greater quantity of mortar is to be prepared than is required for immediate use, and it shall be worked over constantly with hoe or shovel until used; any that has set shall not be retempered or used in any way, and no mortar shall be used more than 1-1/2 hours after mixing.

26. Unless otherwise specified on the drawings or directed by the Chief Engineer, the concrete shall be composed of one volume of cement and seven volumes of sand and gravel or broken stone as the Chief Engineer shall require, but such requirements shall embrace the densest mixture obtainable from the materials furnished. Should the Chief Engineer determine to use a richer mixture in any part of the work, either in the concrete or mortar than hereinbefore specified, the Contractor will be required to furnish and mix such additional cement at the actual cost of such cement plus fifteen per centum, under the provisions in the contract relating to extra work or material furnished.

27. When delivered upon the work the sand, stone or gravel must be kept apart, and protected. Material must be placed on a platform or other hard clean surface (never upon ground) to prevent admixture of dirt during subsequent handling of the materials.

28. The materials used will be measured by methods satisfactory to the Chief Engineer. Measurement by wheel-barrows will be allowed provided the size of the barrow is satisfactory to the Chief Engineer, and provided undue inspection is not required to prevent overloading. If any difficulty develops in either respect, the Chief Engineer will prohibit their use and require each batch to be measured in boxes.

29. The water used in mixing the concrete shall be fresh water obtained from the water supply of the City of Milwaukee.

30. The concrete shall be machine mixed, using a batch mixer of a type which insures the proper mixing of the materials throughout. The mixer shall be subject to the approval of the Chief Engineer. The size of the batch shall not exceed the proper capacity of the mixer. After the complete batch, together with the proper amount of water, measured, by a device approved by the Chief Engineer, is placed in the mixer, the mixing shall continue for at least twenty-two revolutions of the mixer.

31.In case of a temporary breakdown of the mixer, or for any other reason the Chief Engineer may give permission, the mixing may be done by hand, in which case the sand and cement shall be thoroughly mixed dry, after which the stone, previously drenched with water, shall be added. The mass shall then be turned over and mixed with shovels and rakes, the necessary quantity of water being gradually added until the stone and mortar are uniformly distributed. The sand and cement shall be turned over as many times as the Chief Engineer may direct, and after the addition of stone, this also shall be turned over as many times as the Chief Engineer may direct. If such directions are not satisfactory to the Contractor the mixing of concrete shall be discontinued until the machine mixer is in working order.

32. The materials must be mixed wet enough to produce a concrete of such consistency that it will flow into the forms and about the metal reinforcement, and without separation of the coarse aggregate from the mortar.

33. Retempering of mortar or concrete, i. e., re-mixing with water after it has partly set, shall not be permitted.

34. Concrete shall be placed in the work immediately after mixing and be deposited and rammed or agitated by suitable tools in such manner as to produce thoroughly compact concrete of maximum density. No concrete shall be placed until the reinforcement has been previously placed and firmly secured by wiring or other methods to prevent displacement. No wooden blocks will be allowed to support reinforcement.

35. Before placing the concrete care shall be taken to see that the forms are substantially set and thoroughly wetted and oiled. Concrete shall not be mixed or placed at a freezing temperature unless the sand, stone, and water are heated in a manner satisfactory to the Chief Engineer, and proper means must be taken after the concrete is deposited by covering, heating or other methods to prevent injury from freezing.

36. The Contractor shall provide and set up such forms, without additional expense, for moulding the concrete to the proper form as the Chief Engineer directs. All forms used for forming the inner or wearing surface of concrete will be of steel, those forming the outer surface may be either wood or steel, as the engineer directs, but all faces coming in contact with the concrete must be made and kept smooth, true to form throughout, and must be kept well oiled. They must be strongly braced and supported so as to retain their proper shape, and must be so made as to be readily withdrawn without disturbing the concrete. All forms between and upon which concrete is to be laid must be made water-tight and so maintained while in use.

37. The placing of concrete shall be as follows: When the foundations are placed, as directed in each case, the concrete forms for the invert of the sewer shall then be set true to line and grade.

38. Keyways of the sizes shown upon plans, or as directed by the Chief Engineer, must be formed in the concrete at all construction joints. The key forms are to be thoroughly oiled each time before being placed, and must be removed with care before the next section of concrete is poured.

39. The Contractor will not be permitted to deposit the concrete directly in the forms from chutes, but he must deposit it upon platforms built into the trench upon which it will be turned over and deposited into the forms, by shoveling.

40. If, when the forms are removed, any honeycomb or irregular surfaces appear, these must be carefully filled with cement mortar and floated to a perfect surface corresponding to the grade and form of the sewer by an experienced finisher, and immediately after the forms are removed. All inside form faces of concrete shall be washed with two coats of neat cement wash applied by means of a whitewash brush.

41. No forms for concrete shall be removed until the Contractor believes it is safe, and if after removal, any cracks, fractures or improper shapes appear, the concrete shall be taken down and rebuilt at the Contractor's expense. The responsibility for the workmanship in making and placing the concrete rests with the Contractor, who must exercise his own judgment as to the removal of the forms. Before placing or replacing any forms for concrete they must be cleaned of all adhering mortar.

23. REINFORCING STEEL. 42. All reinforcing bars used upon the work shall correspond in every particular with the specifications of the American Society for Testing Materials for "Billet Steel Concrete Reinforcing Bars," and shall be of the structural steel grade either plain or deformed in type.

43. When received in Milwaukee bars shall be stored under cover, protected as far as possible from rust, and delivered upon the work as used.

44. Bars shall be bent to the shape shown on the drawings, and in conformity with approved templets. When bars are cut and bent on the work, the Contractor shall employ competent men and provide the necessary appliances for the purpose.

45. All bars shall be as long as can be conveniently used, accurately bent, placed, spaced, and jointed as shown on the drawings, or directed, and shall be securely held in their position by approved devices until the concrete has been placed around them. Where more than one bar is necessary to complete a required length, they shall be fastened together by approved clamps which will develop the full strength of the bars, or by linking the ends of the bars around each other in a manner which will produce and maintain tension on the joints during construction or by lapping the ends of the bars, as directed, and wiring them together in an approved manner, a distance of 30 diameters for deformed bars, and 50 diameters for plain bars and with a space not less than 2" between them when they are not attached by wiring, clamping or linking. Where one bar crosses another they shall be thoroughly wired together.

24. REFILLING. 46. The materials required for refilling for a depth of two feet over and around the sewers and appurtenances, where built in open cutting, shall be good loam, and gravel or dry clay without lumps. This portion of the filling must, in every case, be carefully rammed by hand with a type of rammer to be approved by the engineer, and used by a careful workman. No backfilling must be placed on top of the arches until the cement has properly set. The backfilling and ramming around and to a depth of two feet over the arches must be done before the centers are withdrawn. There shall be one man ramming to one man filling in.

47. The balance of the refilling shall in all cases, unless otherwise directed by the Chief Engineer, be compacted by power rammers in not over twelve-inch layers. The Contractor will be required to provide sufficient of such rammers of approved type as to permit the backfilling to be properly done without delay. It is the intent of these specifications to get all the materials back into the trenches which may be practically done under existing conditions, and to avoid so far as possible, any subsequent settlement, and the Chief Engineer reserves the right to require the Contractor to use such methods for that and as he may prescribed and without extra compensation.

CHAPTER V.

LETTING OF CONTRACT.

25. ADVERTISING. Proposals for the construction of Section No. 2 of the Menomonee Valley Low Level Sewer were advertised for in the latter part of May 1916, to be received and opened on June 8 1916; The bids to be accompained by a certified check for $30,000 or cash to that amount being 15% of the total estimated cost.

The contract, for convenience in bidding was divided into fourteen separate items but the contract was awarded as a whole. These items are as follows:-

Item (2) 2970 lineal feet of 48" Reinforced Concrete Sewer.
Item (3) 5116 lineal feet of 42" Reinforced Concrete Sewer.
Item (4) 1850 lineal feet of 30" Concrete Sewer.
Item (5) 2610 lineal feet of 24" Terra Cotta Pipe Sewer.
Item (6) 1406 lineal feet of 12" Terra Cotta Pipe Sewer.
Item (7) 20 vertical feet of Drop Manhole.
Item (8) 509 vertical feet of Standard Manhole.
Item (9) 37 Cast Iron Frames and Covers.
Item (10) 75800 lineal feet of Piles.
Item (11) 2000 feet B. M. of 4"x4" Piles under Pipe Sewers.
Item (12) 214000 feet B. M. of Plank Foundation.
Item (13) 106200 feet B. M. of Timber Caps for Foundation.
Item (14) 13000 lineal feet of Underdrain.

The above quantities were only approximate though stated with as much accuracy as possible, but the right to change the quantities as the actual conditions required, was reserved and made a part of the contract.

26. BIDS RECEIVED. The bids received and the firms making them are shown in tabulated form in Table No. 3.

In view of the fact that the contractor would probably be required by direction of the Chief Engineer, to perform some extra work and to furnish some materials not shown upon the plans nor provided for in the specifications, such as brick masonry, concrete, earth excavation, steel reinforcement and lumber, such as sheathing and bracing left in place, it was deemed advisable to fix definite prices for such items, as follows:-

For brick masonry, per cubic yard,------------------	$15.00
For Portland concrete masonry, per cubic yard,-----	8.00
For earth excavation of whatever nature, including back filling or its removal to points directed by the engineer, per cubic yard,---------------------	1.00
For steel reinforcement for concrete in place, per net ton,-------------------------------------	120.00
For sheathing or bracing left in place by order of the engineer, per 1000 ft. B. M.-----------------	20.00
For rock excavation, per cubic yard measured in place, including its removal to such points as engineer directs,--------------------------------	3.00

TABLE No. 3

TABLE SHOWING THE UNIT AND TOTAL PRICES BID BY THE VARIOUS CONTRACTORS FOR THE SEVERAL ITEMS TO BE CONSTRUCTED ON SECTION No.2 OF THE MENOMONEE VALLEY LOW LEVEL INTERCEPTING SEWER

		NAME OF CONTRACTOR							
		Wisconsin Tunnel and Const. Co. Milw. Wis.		Joseph Hanreddy Chicago Ill.		J.H.McKnight Construction Co. Toronto Canada		James Kennedy Fargo No. Dakota	
Item No.	No.of Units	Unit Price	Total Price	Unit Price	Total Price	Unit Price	Total Price	Unit Price	Total Price
1	1		11,950.00		18,000.00		14,980.00		12,836.00
2	2,970 Lin. Ft.	20.00	59,480.00	43.00	127,710.00	25.10	74,547,00	17.00	50,490.00
3	5,116 " "	18.00	92,088.00	32.00	163,712.00	18.25	93,367.00	15.00	76,740.00
4	1,850 " "	12.00	22,200.00	21;00	38,850.00	14.30	26,455.00	13,10	24,235.00
5	2,610 " "	10.00	26,100.00	20.00	52,200.00	11.30	29,493.00	9.00	23,490.00
6	1,406 " "	6.00	8,436.00	12.00	16,872.00	5.40.	7,592.40	7.00	9,842.00
7	20 Vert. "	7.00	140.00	8.00	160.00	10.00	200.00	7.00	140.00
8	509 " "	6.00	3,054.00	7.00	3,563.00	7.50	3,802.50	6.00	3,054.00
9	37	15.00	555.00	15.00	555.0	30,00	1,110.00	15.00	555.00
10	75,800 Lin. Ft.	0.50	37,900.00	o.70	53,060.00	0,35	26,530.00	0.40	30,320.00
11	2,000 B.M. Ft.	50,00	100.00	50.00	106.00	65.00	130.00	50.00	100.00
12	214,000 " "	35.00	7,490.00	40.00	8,560.00	40.00	8,560.00	30.00	6,420.00
13	106,200 " "	50.00	5,310.00	50.00	5,310.00	50.00	5,310.00	35.00	3,717.00
14	13,000 Lin. Ft.	0.30	3,900.00	0.60	7,800.00	0.40	5,200.00	0.50	6.500.00
	GRAND TOTALS---	-------	278,623.00-	-------	-496,452.00-	-------	331,649.40-	-------	-248,439.00

Bids were received on June 8th., 1916

These prices were considered reasonable, and were so fixed because of the inability of the engineer to approximate the quantities of such work as might be required, which estimate must necessarily be made if prices were to be named by each bidder and a comparison of bids be made in the usual way.

James Kennedy of Fargo North Dakota being the lowest bidder the contract was awarded to him and duly executed on June 8 1916.

CHAPTER VI.

CONSTRUCTION.

A. GENERAL.

27. SEWERAGE COMMISSION CONSTRUCTION DEPARTMENT. The executive control of all construction is directly in the hands of the Chief Engineer of the Commission, and his instructions and decisions are supreme. His assistant, known as the Principal Assistant Engineer is in direct charge of all the construction work being done on the new system.

It is the duty of the Principal Assistant to visit the work as often as is possible and confer with and give the necessary instructions to the Resident Engineer in direct charge of the contract If any questions regarding construction, changes, additions etc., arise in the field, that do not materially affect the design and are of too great an import for the resident engineer to assume responsibility for, it is the duty of the Principal Assistant to answer them. His office is located in the main offices of the Sewerage Commission at the City Hall. He has an office engineer clerk, whose duty it is to perform all his stenographic work, keep all supplies used by the field forces, attend to the mail, and all requisitions sent in by the resident engineer, and to tabulate, record and file all reports sent in by the field construction office

The Resident Engineer mentioned has direct charge of the construction work being done under any one contract. His office is located in the field and is portable so that he may at all times be close at hand to the work being done. It is his duty to supervise all the construction work, make special investigations of territory covered by his contract, and offer his recommendations wherever he deems necessary. His position is entirely advisory and supervisory in the field. He keeps all the field records, including costs, distribution of labor, progress etc., and reports directly to the Principal Assistant Engineer.

The resident engineer is assisted by a corps of Engineer Inspectors, one or more, as the work requires, located wherever any construction is being done. It is the duty of the inspector to inspect all the work at his station, set grades and give line and perform other work as the resident engineer may require and direct.

He keeps a record of the progress of the work, labor distribution, materials used, obstructions encountered etc., and renders a daily report to the resident engineer in charge. His grades and line are always checked by the resident engineer who is directly responsible for them finally.

The surveying crew composed of two rodmen and an instrumentman attempt to visit each contract once a day. It is their duty to recheck all grades, insuring against possible mistakes and to run bench mark levels and perform other such work as the engineer may deem necessary. The crew is under the supervision of the Principal Assistant Engineer and is subservient to the resident engineer.

28. PRELIMINARY WORK AND INVESTIGATIONS. The first work done by the Engineer in the field was to make a study of all the obstructions that might in any way interfere with the construction of the sewer on the line as laid out. All railroad tracks, platform wagon scales, driveways, business houses, traffic and so on, were studied carefully to see what interference they might be to the work or vice versa, with the view of changing the line to serve everyone to the best advantage if it could be done.

After the line was determined upon, which on the Menomonee Valley sewer included many changes from the line shown on the plans, test pits were dug on the line at frequent intervals. These pits revealed the presence of any underground structures such as sewers, electric conduits and gas and water mains if any were there and to what extent they might interfere with the work. Accordingly the center line was located and referenced in, so as to clear the conduits if possible or at least so the interference on either side would be a minimum. Conduits crossing the line were not taken into consideration.

The final location of the center line was recorded and any changes made were indicated upon the blue prints. The next step was to run a line of bench marks along the line which would be convenient for use by the resident engineer, and which would not be disturbed by the construction work or other causes. These levels were run by the surveying crew and a copy of the records of all the bench marks turned over to the resident engineer, the original notes being filed in the general office of the commission.

Using these bench marks, record elevations were taken on all the buildings, railroad tracks, scales, sidewalks and curbs, so that if any settlement might occur due to the construction work, it could be detected. Supplementary to these notes photographs were made of every building along the line on both sides of the street and also of any walks or curbs that showed cracks or settlement previous to the start of the sewer construction. These record photographs were mounted and a descriptive statement filed with each one. These records were for mutual protection in case some suit should be started for damage done due to the execution of the work. It is very common to have such a suit instituted and records such as these are a guard both to the property owner and the contractor, the Sewerage Commission assuming no damage claims whatever.

In addition to these records, sketches were made in a note book of all the sidewalks on both sides of the street. On the left hand page was the written record and the date the notes were taken ~~and~~ signed by the recorder; the right hand page contained a sketch of the walk showing the construction cracks in red and cracks going clean through the walk in blue. In some cases the cracks on buildings were also sketched in this "sidewalk book".

29. SPECIAL INVESTIGATIONS. At four separate locations it was necessary to make special investigations because the surface conditions and the available survey notes did not give enough information to properly plan the constuction work.
(a) The case at 15th St. and No. Canal will be discussed in a separate article later on.

(b) At 13th St. and St. Paul Avenue the 24 inch terra cotta sewer crossed the line of the old Menomonee Valley Intercepter, so it was necessary to locate the bottom of the old sewer. There were no manholes close enough to determine the elevation accurately and although the flow line elevations might be determined at the first manholes either side of the crossing and the elevation of the old sewer calculated, this was not deemed sufficient because in several places the old sewer was settled out of place badly and such might have been the case here. Upon examination however, by digging down to the sewer, the elevation as calculated was found to be about right, and by removing one layer of brick from the bottom of the invert the cast iron pipe section shown on plate III could easily be placed in position.

(c) At Tenth St. and St. Paul Avenue the original plan showed the 24 inch terra cotta pipe sewer passing under a 48" circular sewer flowing south on Tenth St. Upon investigation the author found that if built according to plan the new sewer would cut directly through the old one and would therefore not serve the purpose for which it was designed, that of intercepting the flow from the 48 inch sewer. This mistake evidently was due to a blunder on the part of the engineer making the original survey.

It was found that the 30 inch sewer from St. Paul Avenue to No. Canal St. could be dropped bodily 0.34 feet making the flow lines of the 30 inch sewers in the mahhole at North Canal St. the same elevation, there being a vertical drop here of 0.34 feet in the original design. By bringing the springing lines, instead of the haunches of the 24 inch and 30 inches at 13th St. and St. Paul Avenue together 0.25 foot more was gained. Using this and by changing the grade of the 24 inch from a .12% to a .10% we were able to lower the sewer enough to intercept the flow from the 48 inch sewer. The new sewer was stopped about 10 feet west of the 48 inch no attempt being made to carry it under this sewer.

(d) Again, the original plan showed a 12 inch sewer continuing up St. Paul Avenue from the end of the 24 inch sewer discussed in the preceding article, to Seventh St. by way of an alley, Hinman Street and Hill Place. The purpose was to intercept the flow of a sewer in 7th St. flowing south. Upon investigation it was found that this sewer joined an 18 inch sewer coming from the east in the railroad passenger yards and then flowed west down Hinman Street. With the 12 inch intercepting sewer as originally located it would have been impossible to intercept the flow from this sewer and likewise from one coming down 8th St.

Upon investigation it was found that by making the flow lines equal at Tenth St. a 15 inch sewer could be substituted for the 12 inch and placed on a grade so that it would be low enough to intercept the flow from all the above sewers at 8th Street, doing away with about 450 feet of 12 inch sewer, and one intercepter, at a saving to the Commission of some \$3500. The substitution was accordingly made.

(e) The author desires to call attention to the last two special investigations, where, had the sewers been built without some investigation such as made, they would have been utterly useless. By a little time spent, the loss of approximately $25000 in useless construction was averted. He desires to impress the fact of the necessity for thorough examinations and investigations before actual construction begins.

30. CONTRACTORS ORGANIZATION. The contractor received notice to start work on July 1, 1916, but due to various delays did not get started with his organization until late in August 1916.

The organization consists of a general superintendant or manager, who is in entire charge of all the work. He attends to the buying of all materials and equipment, superintends the work in an executive way, and has complete charge of all the finances.

Directly under this manager is the field construction superintendant, whose duty it is to plan and supervise the actual construction work from beginning to end. The superintendant is assisted by a foreman in charge of each branch of the work.

(a) The yard foreman attends to the building of all forms, their storage and care, unloading all materials in the yard, care of the teams, building equipment, preparing foundation piling for driving etc.

(b) The pile driver foreman assisted by subforemen takes charge of the driving and pulling of all steel sheeting, the driving and cutting off of foundation piling and the placing of caps and flooring.

(c) The superintendant himself generally takes charge of all excavation sheeting and bracing, assisted by a high class laborer.

(d) The concrete foreman, builds all backs forms, sets the sewer forms and reinforcing steel and superintends the placing of the concrete. The mixing is in charge of the superintendant.

(e) On the terra cotta pipe sewers, one foreman under direction of the superintendant takes charge of all the work from the excavation to pipe laying and backfilling.

The office force of the general manager consists of a timekeeper and a stenographer clerk.

The duties performed by the various foremen mentioned will be given more explicitly as the description of the construction work is taken up.

31. PRELIMINARY PREPARATIONS. As stated previously, notice to begin work was sent to the contractor on July 1, 1916, and according to the contract agreement actual work should have begun within 20 days after receiving the notice, but nothing was started until after the first of August.

The contractor was very fortunate, in securing a large yard and shop fully equipped, located very conveniently to all parts of the work, and practically in the center of it. The yard was one abandoned by a coal company and furnished ample room for storage of material and building equipment, and is also served by a spur track of the C. M. & St. P. Ry. There are several suitable buildings in the yard including a good barn, a garage, fully equipped blacksmith shop and store room and a steam heated furnished office.

The first work attempted by the contractor was that of installing some new special machinery in the shop and removing a few paving blocks on South Canal Street so as to make a pretence that the work had been started. Next in line was the building of a pile driver for driving sheet piling. This was completed about the middle of August but on account of a delay in transit to the locomotive crane, that was to be used in unloading the steel sheet piling, the driver was not put into use until August 23, 1916.

B. THE 48 INCH CONCRETE SEWER IN SOUTH CANAL STREET.

32. STEEL SHEET PILING. The steel sheet piling used for sheathing the trench for the 48 inch concrete sewer, was second hand material purchased from a contractor who had used it on some work already completed for the sewerage commission. Some of the piling were badly twisted and battered but the general conditions of the entire lot was good considering that it was second hand material. The sheathing is all "Lackawanna" Steel sheet piling of the arched-web type, with 14 inches center to center of webs. There were 500 odd pieces or enough to sheath 300 lineal feet of trench and the piling is all 21 feet lengths. As the average depth of excavation required is about 17 feet and the piling are driven down flush with the ground they have a toe hold of 4 feet below the bottom of the excavation.

The driving of the steel sheet piling is in charge of a sub-foreman with a crew consisting of an engineer, fireman and four driver men. The driver is mounted on 16 feet steel rollers that are well greased. This makes it easy to move the driver front or back, or sideways. In moving, the nigger heads on the engine, which is a Lidgerwood hoist, are used entirely. If the rollers are not long enough to permit sufficient side movement, the frame of the driver is jacked up and the rollers are moved, in the proper direction, one at a time. The hammer is a No. 2 Vulcan Steam Hammer equipped with a special cast cap to fit the end of the Lackawanna sheet piling.

The trench of the 48 inch sewer is parallel to and within a few feet of a railroad track over which a great deal of switching is done every day. It was at first thought that the edge of the trench should be not less than 3 feet 6 inches from the south rail of the track, but it was found that this could be reduced to 3 feet very safely. As being driven at present, the north line of sheeting is 3 feet from the rail. On the south side of the trench is an electric cable conduit, which governs the location of the south row of sheeting. It was found that an eight feet ditch was required and in order to get a trench of that width it is necessary to drive the piling right up against the terra cotta conduit, being very careful not to injure the cable.

The track previously mentioned is a great hindrance to the progress of the work when the row of sheeting next to it is driven. In order to clear the track for switching the driver has to be moved many times during the day, causing considerable delay. It was thought that this could be avoided by having the railroad company do all their switching in the immediate vicinity at night and this plan was accordingly tried out with success, but it is impossible to do all the necessary shifting of cars at night, and therefore some delay still occurs.

The sheet piling drive very hard for the first six feet but from there to the bottom the driving is comparatively easy. The ground being filled in material a piling very often strikes buried objects such as old ties, timbers, piles and even old rails. These very often cause the pile to drive very hard, and in many cases to deflect at the bottom to such an extent that it has to be pulled in order to get the necessary clearance for the sewer walls. This is done after the excavation is completed and floor has been laid.

There has been only one obstruction that materially interfered with the driving of the sheeting and this occurred in the first 100 feet of trench. It was an overhead coal bridge that would not clear the leads of the driver so consequently the leads had to be lowered so that they would clear the bridge. The space under this bridge was sheathed by hand with maple sheeting placed horizontally.

Several spur tracks cross the line of the sewer and two separate methods have been used in driving the sheeting where they have occurred. In all, ten of these tracks will be encountered, four having already been passed. In the case of two of these tracks they were removed entirely, the sheeting driven, falsework placed and the tracks relaid, in the other two the ties were spread and the sheeting driven between the ties. This latter method causes less interruption to traffic and is the less expensive method where the driving of the sheeting is all that is to be considered, however there are other items that enter in, which makes this method undesirable and these will be discussed under excavation.

The largest single days work so far accomplished for driving sheeting is 77 feet, driven on the north side of the trench.

33. EXCAVATION. The main part of the excavation is done by a Browning Locomotive Crane and clam shell bucket. The top material is very hard and compact, and all of it is filled in material. It is very hard for the clam shell to get a "bite" in this top crust and the progress is accordingly very slow.

As soon as the first two feet have been excavated the top set of rangers and braces are put in. The ranger on the track side is an 8"x8" and on the other a 6"x8" flat. The braces are 6"x6" timbers equipped at one end with a 2" trench jack. There are three of these braces to each 16 feet ranger, spaced 8 feet center to center, which gives ample space for the operation of the clam shell bucket. The next set of timbers occur 4 feet and 8 feet respectively below the top set and differ only in that the rangers are all 8"x8" timbers.

The crew doing the excavating and placing the bracing is under the direct charge of the superintendant and is composed of the clam shell engineer and assistant, and four laborers. The laborers place all the timbers and when not busy at this they are picking the material away from the steel sheeting and throwing it to the center of the trench so that the clam shell can get at it.

Under the top crust occurs another layer of filled in material consisting of gravel and cinders very solidly packed. The laborers have to pick this loose before the clam shell can handle it. This is a very expensive procedure and causes a great deal of delay. The excavation is carried on both night and day and still the other operations are always waiting for the excavation.

The writer has suggested several methods of improvement such as a rooting plow, drag line excavator and dynamiting and has finally succeeded in getting the contractor to try out one of them. This has not yet been done but the method will be as follows:- The sheeting will be driven as before except that there will be required about 400 pieces more so as to have ample trench to work on. Large mats will be made to span the trench and strong enough to carry a small steam shovel. This shovel will be used to take off the top seven or eight feet of material leaving the remainder which is soft gray clay and marsh clay for the clam shell bucket. The first two sets of timbers will be placed as soon as the steam shovel has passed and then the work will progress in the usual manner. It is thought that this method or some similar one to hasten the excavation will very nearly dowble the amount of finished work turned out monthly.

Any underground structures encountered during the excavating are carefully protected. If conduits or sewers, they are hung by cables fastened to timbers laid across the top of the trench. All underground services that it is possible to find are located before the clam shell bucket starts digging, so that the dropping bucket does not injure them in any way.

Temporary crossings are provided wherever it is necessary to maintain traffic across the trench. These are built by driving every fourth steel sheet piling on each side of the trench, lower than those adjoining and laying 8"x8" timbers across the trench resting upon these low piling. There are four of these timbers and two layers of 2 inch maple decking are laid on top of them forming a bridge with a 12 feet roadway.

Very often when the bridge is not to remain in position long the above method is not followed, instead, extra trench jacks are put in at the top set of rangers and carefully tightened up and then the 8"x8" timbers are laid from one ranger to the other and blocked up to the required grade. At first thought, such a bridge as this would appear to be inadequate but it was found to be very strong, being able to withstand the heaviest load, a truck loaded with 9 tons of coal, without any apparent deflection. Of course frequent inspections of the jacks are made and the jacks tightened if found necessary.

34. GRADES. Grade battens are nailed to every other brace one side of the batten being on the center line of the sewer. This gives a grade every sixteen feet and very often a batten is placed on every brace. Levels are run by the inspector assisted by a laborer or at times by the resident engineer, and elevations taken on top of the grade battens. From these elevations the distances from the top of the battens down to a line that will be an even number of feet, generally 13 feet, above the flow line of the sewer, are calculated. Notches are then cut on the side of the batten, this distance from the top of the batten. A line then stretched from notch to notch is the center line of the sewer and an even number of feet above the flow line.

It is a very common practice to drive nails in the battens instead of making a notch, but this, in the writers mind is a very poor method of giving sewer grades, especially where the grade is not more than 1/2 an inch per 100 feet, as is the case with a very large number of the new sewers. The nails become bent and are then straightened and even pulled out and driven in again, without the knowledge of the engineer, and for this reason a nail in a batten always has to be checked before it can be used for a grade. It were much better, could it be impressed upon the contractor's men for them not to try to remedy a grade after it had been disturbed but report it to the engineer. This, however, they will not do, because it seems that no man likes to have the blame for disturbing the grade or line.

For the reasons just given, it is recommended that a notch always be used on a grade batten. Of course it is permissable to drive a nail in the notch to fasten the grade line to, as the notch is always there for checking and cannot be moved, but even such nails are not necessary.

The excavation is always carried to 1 foot and 9 inches below the flow line of the sewer as measured from the established grade line and all the dirt cleaned up before the driving of the foundation piling begins.

The material excavated is loaded into ballast cars furnished by the C. M. & St. P. Ry. Company, and shipped to the State Fair Park, west of the city of Milwaukee, where the dirt is disposed of on a land dump. The cars are unloaded by hand, which is a very expensive procedure; During the cold weather the materials froze in the cars and they were very difficult to unload and this was one of the main reasons why the open cut work was not carried on during the colder months.

35. FOUNDATION PILING. The specifications for foundation piling were given in a previous article and mention must be made of the fact that these specifications are all strictly adhered to. The piling are inspected in the yard as they are unloaded and all those that do not meet the requirements are culled out and rejected without hesitation. The rejected piles are painted with a cross at the large end and are never sent out to the works. Of course the piling are purchased subject to the sewerage commissions specifications so that the rejections are no loss to the contractor.

Tamarack and Norway pine is the kind of piling being used and are found to be very good, the only rejections being for under size and dry rot. The contractor attempted to use piling from swamp growth shipped in from southern Illinois. The shipments contained all kinds of wood, all, up to the requirements, but fully 50 per cent of the shipments were rejected. The piling were crooked, undersized, and knotted badly and in driving they would not properly take the weight of the hammer but would splinter and cause the hammer to rebound. It was impossible even with the utmost care to drive the required length of pile straight. Although this type of piling cost much less, there were so many rejections, and such great trouble caused in driving that the contractor at the order of the sewerage commission reverted to tamarack and pine from the northern woods and now experiences very little trouble.

The length of foundation piling to remain in the ground has been established arbitrarily as 30 feet. Shipments of piling therefore contain lengths from 28 feet to 32 feet. Nothing is allowed for any length over 32 feet, although some few of the piling are as long as 35 feet. The piling must be not less than 11 inches at the top and not less than 6 inches in diameter at the bottom and sharpened to a square point. Now and then piling slightly under these dimensions are accepted but if so they are driven so that no two undersized piles are near each other.

In driving, the specifications required extension leads to be used, but it has been found that a follower is much more advantageous. The piling drive very easily requiring about 60 blows from the steam hammer to get them down. The type of driver used is the same as for driving the steel sheathing and is moved in the same way. The crew in charge of the pile driver foreman consists of an engineer and fireman, a nigger head operator and five driver men, one in the trench, one on the leads and three men handling the piles and helping to move the driver when necessary.

The plans require that the piling be spaced two feet each side of the center line at six feet centers, but on account of the narrow trench, which is as wide as it can be made, it is impossible to drive the piling two feet from the center line, even when the follower is used. It is possible to get the piles farther from the center using a follower and this is one of the reasons that its use is permitted.

It is not necessary to use an iron ring on the top of the pile when driving because of the ease with which they are driven. The head is not broomed or split to any appreciable extent and if it is seen that the pile has a tendency to drive hard the ring is put to use so as to guard against splitting, this however being seldom necessary.

Should the pile as it is driven get out of place to such an extent that in the opinion of the engineer, it does not properly serve its purpose, a new piling must be driven along side of it and no pay be allowed for the first pile. The piles must be kept in as near a true line, parallel to the sewer, as is possible, so that the caps will have proper bearing on the piles without breaking the caps except every 18 feet.

The piles are not permitted to be driven to grade but are left high and each one sawed off so that the caps have a perfect bearing on the top of the pile. Adzing is not permitted nor is a shim less than 2 inches used. To date no shims have been used.

As the piling are brought to the driver they are measured and their lengths recorded by the inspector. It is not necessary for him to watch the driving, but he is always present when the piles are cut off so that no mistake is made in grade. As the piles are cut off a record is kept of the lengths cut off but nothing less than six inches is deducted. The amount remaining in the ground is reported by the inspector and it is this amount that the contractor is paid for.

The largest number of piles driven, cut off, and capped in one day up to date is 28. More time is required to cut off a pile than to drive it. The foundation pile driver is at work only a small percentage of the actual time being always held up by the excavation.

36. CAPS. The caps being used as required, are of good sound yellow pine in 18 feet lengths. The caps are placed so as to get full bearing on the piles and if this is not possible the caps are cut over the center of the pile so that they do have proper bearing. The caps are drilled by one inch ship augers through the center, directly over the piling. Steel pins one inch in diameter and 18" long with a pointed end are driven through the cap down into the pile, thus holding the cap securely in position.

37. UNDERDRAIN AND PLANK FLOORING. The ten inch terra cotta underdrain and the plank flooring are laid simultaneously. The T.C.pipe drain is laid between the caps with the outside of the bell on a level with the top of the caps and dirt is carefully backfilled all around the pipe and between the caps. Care is taken to get good joints in the drain and a 3/4 inch rope is drawn through the pipe as it is laid to be used for cleaning if found necessary.

The flooring being used is of second quality, coming in lengths of six feet and widths from 6 to 12 inches nothing less than 6 inches being permitted. Considerable flooring is culled out and rejected by the inspector. The culled planks however are made use of, other places about the works. The first layer of flooring is laid with the center of the plank on the center line of the sewer, by one man, followed by two men who spike the plank to the cap using two 20d. spikes in each end of the plank. The second layer is then placed on top and spiked to the first with four spikes to a plank. Care has to be used in nailing because the planks are very hard and the spikes bend easily.

After the floor is in place it is braced down every few feet by a 2"x4" strut between the floor and the bottom set of timber trench bracing. Cases are known where the water has risen over night and caused considerable upheaval of the flooring. This bracing is a guard against any such occurrence.

38. BACK FORMS, INVERT REINFORCING AND INVERT FORMS. A back form was designed made up of one inch hard maple material to be moved in units. On the bottom of the vertical studding of these forms was a 3/4 inch iron pin which fitted into a hole drilled in the plank flooring. This kept the form to line and likewise from spreading at the bottom. At the top of the form were hinges designed for fastening the arch blanket forms to.

These forms were used for a while but so much time was spent in recovering them and keeping them in repair that they were abandoned. At present forms are being built in place using second class cheap lumber, and are braced against the sheeting to keept them from spreading. Whatever salvage possible is recovered and the rest of the form is left in the trench and covered up. Figure VII shows the back forms and flooring in place ready for steel and invert forms.

The invert reinforcing consisting of two 3/8" horizontal rods on each side and 1/2" vertical rods 5 feet long at 8 inch centers, is all wired together and is then hung from the heads of spikes driven into the back forms. This method keeps the reinforcing off of the floor and likewise holds it the proper distance, two inches, away from the back forms. The steel is placed as soon as the back forms are in position and before the invert forms are set.

The invert forms being used for this 48 inch sewer are of steel and are rented from the Blaw Co. . They are a half circle and in five feet lengths with two turnbuckle braces to each form. The forms have a lap joint and are connected by staples in one form going through corresponding slots in the next form. The forms are drawn up by driving wooden wedges through the staples. The steel is about a no. 14 gauge material. The forms are all carefully cleaned and oiled, before being placed.

Grade blocks of concrete on which to set the forms are used when the full sewer is being poured monolithic but when only half of the barrel is concreted at a time grade blocks are not permitted.

Experience has taught the commission that wherever leaks occur in the invert of a sewer, 90 percent of them are found near the grade blocks when these are used, because the concrete is not successfully tamped around the blocks, leaving porous spots. For this reason grade blocks are not permitted where it is possible to dispense with their use.

The contractor attempted to use chain falls for hanging the invert forms using two sets on every second form. This method did not prove to be a success, as was obvious to the writer before it was tried out. One accidental pull on the chains would throw the forms out of line making them either high or low, and such accidents are bound to occur.

The writer devised a method of hanging the forms from jacks and this method is now being used entirely. The photograph in figure VIII shows how these jacks are used in supporting the forms.

The jack is a simple trench jack slotted to receive the hanging hooks. It is tightened against the steel sheeting and supports itself and the form, entirely by friction on the sheeting. In figure VIII (a) the hanging hooks hold the form up, and (b) wedges and blocking between the jack and the form keeps the form from being forced up by the concrete pressure. The form is held to the center line by a notched 2"x4" (c) that fits over the form and extends out to and is braced against the back forms.

After the invert forms have been set, the grade and line are carefully re-checked by the inspector and the forms are checked up with this rechecked line. The forms must be perfect before any concrete is permitted to be placed.

39. CONCRETE (INVERT) The general specifications for concrete are given under the article on "Specifications" and reference should be made to them at this time.

The sand and gravel being used for the concrete work are both A No. 1 washed products furnished by the Waukesha Lime and Stone Company of Waukesha, Wisconsin. The material is a bank run gravel that is passed through a crushing plant and is then thoroughly washed and screened to size. The sand contains some few lime stone chips but very few, and likewise some lime stone occurs in the gravel but most of the particles are of very hard flinty substances. These same materials are being used extensively on concrete roads being built by Milwaukee County, Wisconsin, and give excellent results. The gravel used on the 48" sewer is well graded all to pass a 1 1/4" ring.

"Newago" cement is used entirely. This brand was selected by the contractor and was accepted by the sewerage commission as meeting all requirements of the specifications. A large supply of the cement is always kept on hand in a warehouse on South Canal St, very near to the contractor's yard, so that no delay may be caused waiting for tested cement. The cement as it is unloaded is tested by the testing department of the city, and reports on the same rendered to the sewerage commission.

The mixing of the concrete must be thorough and the inspector sees to it that this is done. The concrete mixer being used is a "Smith" steam mixer 1/2 cubic yard size, which has a speed of 12 R. P. M. Since the specifications require that the drum make 22 revolutions for each batch, the mixture remains in the drum for a little longer than a minute and a half. This time could be shortened by speeding up the mixer and just as good a concrete would result, but the contractor figures that the wear on the machine is too great when operating any faster, although the manufacturers

FIG. VIII

recommend a speed of about 15 R. P. M.

The water used is ordinary clear lake water drawn from the city hydrants the amount for each mixture being measured by the devise for that purpose on the concrete mixer, just above the drum. The water is put into the mixer at the same time that the dry materials go in. Two sack batches are mixed. The sand and stone is measured in wheel barrows, small enough so that theycannot possible be overloaded. The quantity of each material has been figured from void tests so as to give the densest concrete possible and gives a proportion of about 1:2.70:4.30. These figures are not in cubic feet as is generally the case but as stated in the specifications the cement sack with a volume of 0.92 cubic feet is the unit used. In cubic feet the proportion would be .92:2.48:3.95.

The amount of cement required per foot of sewer has been figured out very carefully and this amount is checked up with the cement used on each run. If there is any discrepancy on either side, an investigation is made and the trouble corrected. It is not the policy of the commission to ask for more than the specifications call for and if more cement is being used than is necessary the contractor's attention is called to the fact. The materials used have been found to vary but little and therefore the required amount of cement does not change to any appreciable extent.

The concrete is discharged from the mixer into a steel, hoppered, car with a gate in one side near the bottom. This car runs on a track along the side of the trench to where the forms are ready, and the concrete is spouted down to a movable platform resting on the bottom set of trench timbers. The specifications do not permit spouting directly into the forms as this results in the materials separating but the concrete must be first deposited on the platform and the separated particles again thoroughly mixed before the concrete is placed in the forms. As the concrete is shoved from the platform into the forms it is tamped and spaded thoroughly by four men, two on either side. These men also keep the concrete cleaned up that accidentally falls outside the forms, and at times tap the forms with a four pound hammer. This tapping breaks up the air bubbles that collect near the forms and allows the mortar to fill the cavities and as a result the surface is very near perfect when the forms are drawn.

The concrete is placed in two lifts, the first lift coming to within 18 inches of the top and the next to the top of the forms. At first four and then three lifts were used but two lifts has been found to give the best results. Very little trouble is given the inspector in seeing that the material is well spaded because, the foreman has learned by experience that it is easier to do good work to start with, than it is to finish up poor work, as required, after the forms are removed.

Keys made from 2"x4" material ripped in half are placed in the concrete at the springing line as soon as the forms are filled and the surface of the concrete is left as rough as practicable so as to give a good bonding surface between the invert and the arch of the sewer. Similar keys are also fastened to the bulk head placed at the end of a days run so as to form a better bond between adjacent sections poured.

The invert forms are not removed until the concrete has set thoroughly for at least 24 hours. As soon as they are removed, any porous spots, if there be any, and they are rare, are thoroughly filled with cement mortar; the entire surface of the newly poured invert is then painted with a thick cement wash, no sand being used in it.

This wash fills all the small air bubble holes and gives a very smooth finished surface. This must be well set up before any one, is permitted to walk on it. The invert is generally kept two days ahead of the arch so that it can be properly finished before the arch forms are set up.

40. ARCH FORMS, REINFORCING AND CONCRETE. The arch forms used are the invert forms turned over. A 2"x6" piece is cut just to fit across the invert about 2 inches below the springing line and this supports the form. Wedges are used to bring the form up to grade. A 2"x4" strut is put in from the crown of the form down to the concrete so that it is impossible for the form to sag. The turnbuckle braces keep the forms spread.After the forms are set they are well cleaned and then oiled before any reinforcing is placed.

The vertical rods mentioned under the discussion of the invert reinforcing protrude from the concrete about 2 1/2 feet. These rods are bent over so that their free ends are about 3 inches from the steel arch forms. To these bars are wired 1/2" rods 7 feet 6 inches long that have been previously bent to a semicircle. At the center these arch rods are spaced 2 inches above the forms. The longitudinal bars, five of them are 3/8" and are spaced as shown on the detail drawing for the 48" sewer in plate II. Each longitudinal bar is wired to every arch bar.

After the steel has been placed the keyways and bench walls are cleaned and brushed with a wire brush before the blanket forms are set. These blanket forms are made up in sections and are fastened to the wooden back forms already described. They are held up from the forms by a 9 inch spreader and are braced down by a strut to the trench bracing just above the forms. Figure IX shows the arch forms in place with the steel and blanket forms already for the concrete.

The same crew as is used in concreting the invert attends to the arch concreting. The crew is in charge of the superintendant and consists of a mixer engineer, a cement man, 3 men wheeling sand and stone, 2 men pushing the concrete car, one man holding the spout in the trench and 4 men, one being the concrete foreman, spading the concrete as it goes into the forms.

Before any concrete is placed, a thin 1:2 mortar is spread out on the bench walls so that the keyways are sure to be well filled and then the concrete is placed from a platform, in the same way as the invert concrete is placed. The arch is poured in two lifts and all the concrete is thoroughly spaded. At times the concrete is spouted directly into the forms, on the last lift, contrary to specifications, as it has been found,if carebe used,that this gives results that are satisfactory.

The steel forms are designed to be moved as a unit, all the sections coupled together but this is not being done. The forms are all taken apart and each section moved ahead separately. Dragging the forms over the green concrete, which is absolutely necessary when the forms are moved as a unit, injures it to a considerable extent, so that this method of form moving is discouraged as much as possible

With the work operating as it should, concrete should be poured every day. It takes little time to place the concrete after the forms are set, but as usual the work is held up waiting for excavation. The largest days work in concreting up to date is 55 feet of invert and 65 feet of arch on the same day. There are 150 lineal feet of forms available.

Bottom of 48" Trench

FIG. IX

41. BACKFILLING. The following day after the concrete arch has been poured, the back forms and the arch blanket forms are removed and any porous spots that occur on the outside of the barrel are plastered up with mortar; then material from the trench ahead is carefully backfilled and well tamped all around the finished sewer to a depth of two feet over the top of the arch. This is done before the arch forms are removed.

After this amount of backfilling is in place the arch forms are removed and the surface painted with the cement wash, immediately.

The backfilling continues using a Western Dump car. The car is loaded by the clam shell with wet material if possible so that no tamping is necessary. If the material is dry, it must be spread out in layers and thoroughly tamped. Four 3"x12" planks are laid on the second set of timber bracing and the material from the car is dumped into these planks so that the weight of the fall does not come directly on the sewer. The more sloppy and wet the material is, the less tamping is required. The timber bracing is removed as the backfilling reaches it.

42. MANHOLES. Manholes for all concrete sewers as shown in the detail plans on Plate II and as given in the specifications are supposed to be built of brick, but there are difficulties that arise which makes brick construction very expensive. There are no brick made in Milwaukee, nor even in the close vicinity that will meet the requirements of the specifications so that nearly all the brick that are used, have to be shipped in from Central Illinois cities. The shipments are often delayed and then too there is always delay and trouble in securing a good brick mason, unless one is employed regularly and this is not probable. One brick manhole has been built, the first one, but the rest have been and probably all those to come, will be built of concrete.

A standard set of forms for the manholes has been built and are being used very successfully. The outside form is square with the corners cut off and is built of very cheap lumber. The concrete is mixed in the ordinary manner and is then spouted directly into the form with due care so that the materials are not separated. It is carried up to within about 15 inches of the street grade, and after the concrete has set and the forms are removed a ring of good brick is laid on top of the concrete and the casting is set in mortar on top of these brick, bringing the top of the casting up to the street grade.

The details of this casting are given in Plate III. The approximate weight of the frame is 425 lbs, and that of the cover 225 lbs.

43. PULLING SHEETING. For pulling the steel sheeting the contractor built a special puller. It is equipped with an American hoisting engine. Two sets of three sheave, steel blocks, giving a mechanical advantage of six at the connection to the piling, pulls the sheeting with ease, except where in some cases no back form was used on account of not enough clearance, and the concrete was separated from the sheeting, by a layer of tar paper only; These sheeting were started but with considerable trouble.

As the sheeting is withdrawn fine sand is washed into the cavatity left by the sheeting so that no settlement will be caused. A great deal of sand is used up in this manner in fact such a large amount that the procedure becomes very expensive, but it is required of the contractor, because a great deal of settlement occurs when sand is not used. The sheeting are dragged away from the puller to the sheeting driver that is generally operating at the same time by one team of horses.

The crew operating the sheet pile puller is in charge of a sub-foreman and consists of an engineer and fireman, nigger head operator, two pile driver men, and two laborers who handle the sand.

44. FINISHING. After the sheeting has been pulled the excavation is carefully levelled off leaving the material high enough to take care of any settlement. Where crossings are necessary, planks are laid on sills embedded in the ground.

As the work progresses all the rubbish, lumber and debris is cleaned up, The paving blocks are not being replaced at present and will not be, until the trench has had sufficient time to settle. When the pavement is replaced, a gravel base 6 inches deep will be placed under the blocks. This is the same foundations as was there when the pavement was removed.

It is possible that the contractor will not be required to replace the old pavement as the city contemplates placing a new pavement on this street. Should this be done some agreement would probably be reached by which the contractor would pay to the Department of Public Works, to be used toward the new pavement, an agreed amount per lineal foot of trench opened, equal probably to what it would cost him to replace the old pavement.

45. COSTS. The month of October 1916 is a representative month as regards the amount of work done as it is being prosecuted under the present methods. The table of costs following are figured for the month of October, and is given as an example of how the cost records being kept are made use of.

46. RESUME. Work on the 48 inch sewer, closed on January 1, 1917, and it has not as yet been resumed. It is expected to be in full swing again by April 1st, and should be completed by the middle of the summer.

In in the opinion of the chief engineer, the sewer thus far completed is practically perfect, as regards grade, line, and construction, and easily fulfills all the conditions for a value of "n", the coefficient of roughness equal to 0.013. This same standard will be maintained on all of the construction work carried on under the direction of the writer.

C. 42 INCH CONCRETE SEWER ON SOUTH CANAL STREET.

47. GENERAL DISCUSSION. No work has as yet been started on the 42 inch concrete sewer. However it is planned to use the same method of construction that has been followed in building the 48 inch sewer with whatever minor changes that may be found necessary.

It is possible that the work on this sewer will be started inApril as soon as the weather permits and be carried on at the same time with the 48 inch , unless the rate of progress on the latter is materially increased. This will be necessary in order to complete the work yet to be finished, before the winter of 1917. It is not desirable to have this section of the system tied up over another winter, so every means will be used to push the work to completion by fall.

TABLE SHOWING DETAIL COST OF CONSTRUCTION FOR THE 48 INCH SEWER

Steel Piling---Driving & Pulling	Labor	3.47	
	Ins.	.42	3.89
Evcavation, Bracing & Backfilling	Labor	2.61	
	Ins.	.31	
	Disposal	1.61	
	Plant Etc.	.25	4.78
Foundation Piling Driving & Cutting	Labor	.07	
	Ins.	.008-	
	Piles	.11	
	Plant Etc.	.032	2.20
Caps, Placing, Doweling & Cutting	Labor	.12 /M	
	Ins.	1.21 /M	
	Material	30.00 /M	.44
Flooring, Laying and Spiking	Labor	4.33 /M	
	Ins.	.52 /M	
	Material	24.00 /M	.635
Underdrain, Laying Etc.	Labor	.083	
	Ins.	.009	
	Material	.15	.242
Concrete, Invert & Arch	Labor	1.66	
	Ins.	.20	
	Rein. & Lab	.95	
	Cement	1.40	
	Sand	.31	
	Stone	.57	
	Forms	.40	
	Cleaning	.10	
	Painting	.12	
	Plant Etc.	.30	6.07

Total Construction Cost per Lineal Foot of Sewer	24.257
" General Cost per Lineal Foot of Sewer Including Superintendance, Clerk, Timekeeper, Watchman Etc.	1.97
Estimated Bond Cost per Lineal Foot of Sewer	.47
" Cost per Foot of Sewer Including Stationery, Travelling Expenses of the Contractor, Etc. 5%	1.213
Total Approximate Cost per Foot of Sewer Constructed During the Month of October 1916	27.91

Note:-

These costs will vary considerably from month to month and are given here only to show how the records kept are made use of.

The estimated bond cost given above is figured on the basis that 1/12 of the total bond cost applies to the month of October. This amounts to $206.66. This latter amount was distributed per lineal foot of sewer built.

Instead of using half circle forms, the entire barrel of the sewer may be built monolithically. If this be done it will mean considerable more work in placing the steel reinforcement and this accordingly will raise the cost. This added cost might be offset by the advantage gained in not having so much steel sheeting tied up. The contractor was advised to pour the 48 inch sewer as a whole, but for various reasons, preferred the method now being used. These same reasons may prevail and cause him to use half circle forms. In the opinion of the writer the monolithic method is the proper course to follow, because of the advantage mentioned above, the better results, that is a more nearly water tight sewer by cutting out the joint at the springing line, and the reduction in cost that probably would occur.

Of course the engineering department does not hold the contractor to any certain method of construction nor does it dictate so long as the contractor obtains the results from whatever method he may choose to use.

In passing under the tracks of the C. M. & St. P. Ry. Co., on South Canal St., and those paralleling Greves Street near 27th St., the Railway Company will be required to install falsework, to carry the tracks while the sewer is being built. The expense of this work is to be born entirely by the Railway Company, and the falsework may be of any type that it may choose to use. In all probability a bent of piling will be driven under each track on both sides of the trench, and the track carried over the trench on a single set of timbers.

If arrangements can be made with the Railway Company, the steel sheeting piling and the foundation piling will be driven by one of their track drivers. If not the excavation will be carried on by hand and the trench sheathed with horizontal wood sheeting, and traffic will have to be held up while the timber piles are being driven. In order to avoid this delay the Railway Company can undoubtedly be prevailed upon to do this work for, and charge the cost of the same to the contractor

D. THE 30 INCH CONCRETE SEWER IN MUSKEGO AVENUE AND IN GREVES STREET.

48. GENERAL DISCUSSION. No construction work on the 30 inch concrete sewers has as yet been started. There are only 1850 lineal feet of this size of sewer to be built and this will probably be left until the terra cotta pipe sewers have all been finished.

The first section to be started will be that from the Menomonee River, north to St. Paul Avenue; second the section south of the river to South Canal St., and third and last the sewer in Greves Street.

The average depth of the 30" sewers is about 14 feet. At this depth an excavating machine can be used very economically and probably will be. The contractor at present has a Parsons, ladder type trenching machine in operation on the terra cotta pipe sewers, and this machine may be used; if not, the contractor has two other large trenching machines that are at present working in Kenosha, Wisconsin, and which will be released in about two months, at which time one or both of them can be started at the excavation for the 30 inch sewers.

As planned, wood sheathing will be used throughout on this size sewer. The excavated material not used for backfilling will be disposed of on land dumps, which are located conveniently to both streets.

It is not known whether foundation piling will be required or not but the indications are that piling will not be required north of No. Canal St.

In excavating for the 24 inch sewer already completed in No. Canal St., at Muskego Avenue, the soil was found to be very good and this would in all probability continue to the north. Should this be the case the "firm earth section," shown on Plate II will be used. This same condition will also no doubt be found in Greves Street.

It is not expected however that piling can be omitted on the sections on either side of the river as this undoubtedly will be soft ground. Should this not be the case the firm earth section, will be used here also.

It is now planned to tunnel under the tracks on Muskego Ave, but, should soft ground be encountered, it will be necessary to drive piling and the work would have to be handled, working in coöperation with the Railway Company, the same way as was described under the discussion for the 42" sewer preceding.

The forms to be used on this sewer are full circle steel forms, the property of the contractor. These will be set up on grade blocks and each section of the sewer poured as a monolith. The concreting will receive the same attention as that for the 48 inch sewer already described, but wheel barrows instead of the dump car will be used, the mixer being moved for each day's concreting.

In favorable weather at least 65 feet of this size sewer should be completed at each day of concreting. If it is warm enough the forms may be collapsed and moved as a unit the day after the concrete has been placed. The forms will be pulled ahead by a hand winch, the forms rolling on dollies. It is very probably that the amount of excavation accomplished each day, will govern the speed of the concreting and that the forms will remain in place, longer than just over night.

No backfilling over the sewer will be permitted until the concrete has set for at least two days. As the backfill is placed it will have to be very thoroughly tamped so that the pavement may be replaced with the least possible delay. Muskego Avenue is a very busy thoroughfare and the full street must be turned over to the traffic as soon as it is possible. The same is true of Greves Street.

The inside of the sewer will have to be finished from day to day so as to get a perfectly smooth surface, free from defects. The same methods will be used as were described for the larger sewers. Closer inspection will be required, however, because of the smallness of the bore. A laborer is very reluctant to stay in a small sewer for any length of time and will slight his work in order to get out as soon as possible. This condition will have to be guarded against and a perfect finish demanded.

E. THE 48 INCH CAST IRON PIPE SECTION ACROSS THE HOLTON CANAL.

49. GENERAL DISCUSSION. When the survey on South Canal St., was made, there were no soundings takem inthe canal on the c'tr line but instead they were taken both north and south of the bridge. The same depth of water as determined, was assummed for under the bridge on the line of the sewer.

Acting on this assumption, a cast iron pipe section was designed, for crossing the canal. The pipe was to be placed on pile bents spaced every six feet and the pipe strapped down by a 3"x½" iron strap fastened to the sides of the caps and the foundation piles. Wedges of hard wood were to be used under the pipes to keep a true grade and alignment.

A section of this type was designed because it was assummed that the pipe could all be calked above the water and then lowered as a unit to the pile bents, and a diver sent down to place the wedges and the straps. This method would have been very good, had the actual conditions been as they were assummed, but they were not.

The resident engineer made an investigation and found that there was only about four feet of water under the bridge. Accummulated dirt that had fallen through the bridge decking had filled up the canal to this depth. Originally there was no bridge on So. Canal St., and this canal was navigable from the Menomonee River to the South Menomonee Canal, but now, it is used from either direction up to the bridge only, the canal really being divided into two separate slips which are entered from the north and south respectively. The entire Holton Canal, however, acts as an equalizer between the River and the South Canal.

Since the canal was filled up to such an extent the original method of laying the cast iron pipe had to be abandoned. If the trench had been excavated without sheathing, the entire canal bottom would have slid in for several feet each side of the trench. The contractor therefore decided to drive steel sheeting across the canal just as is being done with the 48 inch sewer, and since this is to be done, the idea of using cast iron pipe, will be abandoned. The same type of concrete construction as is used in the remainder of the 48" sewer will be used instead.

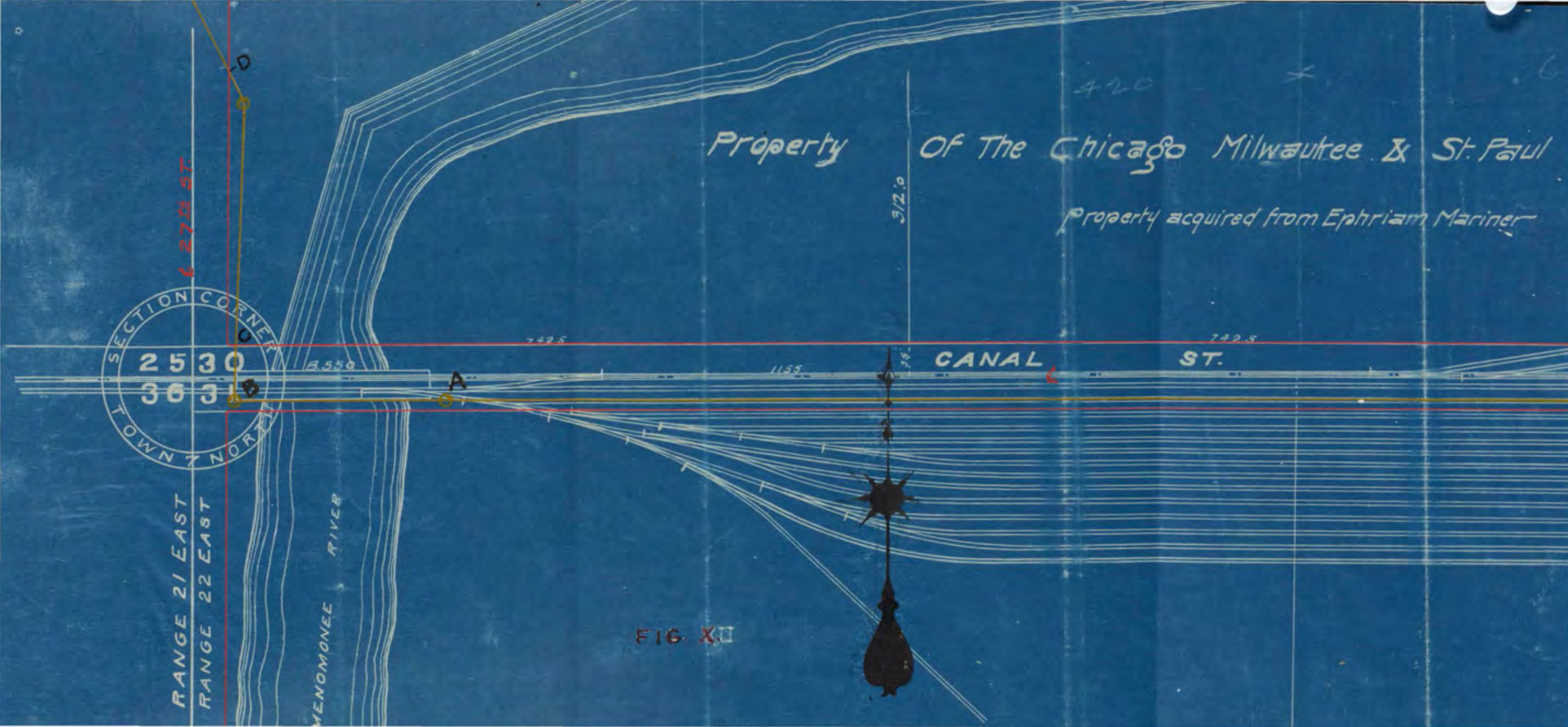
It is thought that this change will mean a saving to the contractor of over $500.00. The contract price for the cast iron section is the same as that for the concrete sewer and since concrete will serve the purpose just as well as cast iron, the commission has granted the contractor the right to make the substitution mentioned above.

The contractor had planned on laying the cast iron pipe across the canal during the winter months, but since the change has been made no work has as yet been started. This will be the first section to be started as soon as the weather conditions permit.

F. THE INVERTED PRESSURE SIPHON UNDER THE MENOMONEE RIVER AT 27TH STREETH.

50. ALIGNMENT. South Canal St. from 20th St., west to beyond 27th St., is occupied by a frieght yard of the C. M. & St. P. Ry. Co. There are two main lines traversing the entire length of the street one on the center line of thestreet, and the other one 15 feet to the south. North of 20th St., the center line between the two tracks is on the center line of the street and here the center line of the sewer is 17.3 feet south of the street center line. If this same line were extended, the sewer would run directly into the south main track in the railway yards, and this had to be avoided.

The sewer line was therefore broken so that this trouble would be avoided. Fourteen feet south of the south main track is a storage track that is used less than any other track in the yards



Property Of The Chicago Milwaukee & St. Paul
Property acquired from Ephriam Mariner
CANAL ST.
SECTION CORNER
25 30
36 31
TOWN 7 NORTH
RANGE 21 EAST
RANGE 22 EAST
MENOMONEE RIVER
A
B
C
D

FIG. XII

It is 5 feet off of the south property line. Since one track had to be abandoned while the sewer was being built, this one was chosen and the center line of the track assumed as the center line of the sewer. With a trench 8 feet wide there would yet be one foot to spare before the trench would encroach on private right of way. The track will have to be removed and relaid by the Ry. Co. at its own expense, since the track is in the street.

This same line is extended to and across the Menomonee River at 27th St., and forms the center line of the river siphon. The two main lines mentioned above are carried across the river on a timber pile trestle and the siphon must clear this trestle; likewise private property must not be encroached upon; therefore the line of the siphon is practically tied in as located.

Figure X shows the Railroad yards in the vicinity of 27th and South Canal St. The yellow line indicates the center line of the sewer as now established, and the red lines are the property lines. It is noted that from (C) to (D) the sewer is on private right of way; this was necessary, in order to clear some buildings on 27th St., between (C) and (D). This right of way was secured with difficulty and the line here cannot be changed. It must here be stated that 27th Street at this location, is not city property. The street viaduct is operated under some legal agreement with the owners of the land.

The riser shaft of the siphon as located, would be at (A) By referring to figure X it is seen that if the shaft is built as located, it will mean the closing of the main lead to the yard ladder track and the building of considerable falsework, and the same would be true even though the shaft be moved farther to the west. This fact was brought to the attention of the Engineering Department of the railway company and the suggestion made that the shaft be moved to the south about 20 feet onto the private right of way. This change would be a material benefit to both the contractor and the railway company, but the railway officials were obstinate and said that the line must remain as originally located. This is not final however, and some change will yet be affected so that the conditions mentioned will be remedied.

51. CONTRACT SUBLET. James Kennedy the contractor is not equipped for doing marine work and did not care to attempt the construction of the siphon across the river. Although the work will be done in open cut, he still feared that conditions would be encountered that he could not properly combat and accordingly he sublet the building of the siphon to the Gillen Company, marine contractors of Milwaukee, Wisconsin.

52. COFFER DAM. Although the construction work has not as yet been started the contractor plans to build one-half of the siphon at a time, closing off only a part of the river. The siphon will be 10 feet below the water level so there will not be very great pressure on the coffer-dam. It is planned to drive only a single row of steel sheeting and as the material is excavated it will be placed directly outside of the sheeting. This it is presumed will make a water tight dam. The sheeting may have to be calked if any leaks occur but even then, considerable expense will be saved if a double wall coffer-dam does not have to be built.

53. EXCAVATION, ETC. The excavation will undoubtedly be carried on with a clam shell bucket in the same manner as it being used on the 48" concrete sewer. The material will be disposed of on a

land dump just west of the river and south of the tracks. The ground is all very low and no charge will be made for disposal.

The trench bracing will be the same as that used on the larger sewers, 8"x8" rangers and 6"x6" timber braces with 2" trench jack screws in one end. Three sets of timbering will be required in order to make the trench absolutely safe.

54. PILE DRIVING. Arrangements with the Railway Company are contemplated, by which the company will drive both the timber foundation piles and the steel sheet piles in the coffer-dam, with one of their track drivers. This method would be by far the least expensive, but the sub-contractor may have some difficulty in getting the railway officials to do this work. If not successful, a land driver will have to be used and false-work driven. The foundation piles and the coffer-dam would then be driven simultaneously, two piles one on each side of the steel sheeting and the two foundation piles forming the falsework bents. The foundation piles would of course be much longer than necessary so that when cut off the proper length of pile, 20 feet, would be left in the ground.

Grades for both excavation and cutting off the piling will be obtained from grade battens in the same manner as described in detail under the discussion for the 48" concrete sewer.

55. CAPS AND FORMS. The foundation caps to be used are 6"x8" timbers 5 feet long of good solid pine wood, doweled to the piling by 1 inch round steel pins 18" long. Refer to Plate V for a detail drawing of the foundation caps and piling.

No forms for the bottom of the concrete are to be used unless conditions require them. If the soil is soft wet and mucky it may be necessary to use a rough plank floor or possibly some crushed stone placed on the bottom trench will serve the same purpose, that of preventing the concrete from mixing with the mud in the bottom of the trench.

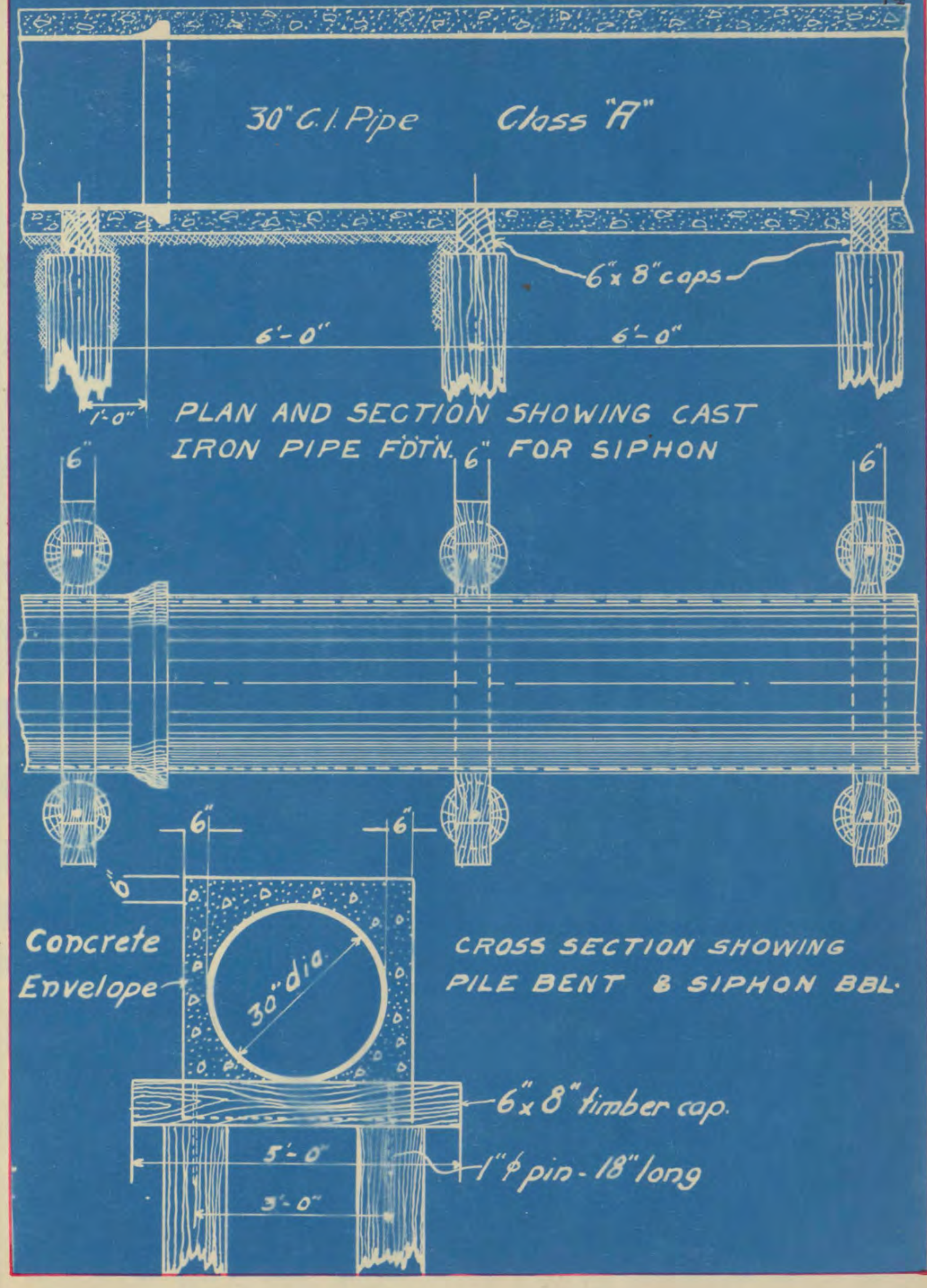
Rough side forms for the concrete will be built, resting on the caps with possibly an upright set up between the pile bents. The forms will be braced on the outside against the coffer-dam to prevent spreading.

56. CAST IRON PIPE:

(a) Specifications. The cast iron pipe and specials shown upon the plans to be furnished shall be Class A, of the dimensions as shown upon the plans, corresponding in all particulars with the standard specifications adopted by the American Society for Testing Materials. The pipe shall be inspected at point of manufacture by an inspector in the employ of the Sewerage Commission, and only such pipe as may be accepted by said inspector will be accepted. The Contractor must give the Chief Engineer all information concerning the place and time of manufacture to enable him to provide inspection to the end that no delays shall be experienced in the delivery of pipe

(b) Laying and Calking. The pipe will be distributed by the Contractor as required, and care exercised to prevent injury in handling. Proper tools and implements satisfactory to the engineer for safely handling the pipe and other materials will be provided and particular care exercised to prevent the abrasion of the pipe coating which will be repainted, if injured, by a coal tar varnish properly mixed with oil and heated before applying.

PLATE V.


30" C.I. Pipe Class "A"
6"x 8" caps
6'-0"
6'-0"
1'-0"
PLAN AND SECTION SHOWING CAST IRON PIPE FDTN. FOR SIPHON
6"
6"
6"
6"
6"
6"
Concrete Envelope
30" dia.
CROSS SECTION SHOWING PILE BENT & SIPHON BBL.
6"x 8" timber cap.
5'-0"
1" ϕ pin - 18" long
3'-0"

All specials must be furnished and set as required and shown upon the plans without additional compensation.

Each pipe must be cleaned of all debris, stone, dirt, etc., and inspected for cracks before being laid, and if found cracked the cracked portion cut off before being laid. The bell of the pipe must be wiped out before inserting the clean spigot of the next pipe which will then be shoved home firmly against the bottom of the bell in such a manner as to prevent the pipe becoming displaced after the joints are poured with lead. The pipe must be laid to line and grade as shown upon the plans.

Only good sound hemp yarn or jute packing, braided or twisted, cut off in lengths as necessary and tightly driven home, may be used.

The depth of the lead joints will be two inches, and the lead must be of the best quality, pure and soft and suitable for calking. The lead melting pot must at all times be kept close up to the joint being poured, so that the lead may under no circumstances, become chilled in being carried to the joint from the melting pot. The joint must be run at one pouring, using such ladles as may be necessary, and be calked by skilled mechanics, using at least two sets besides the small chisel, in such a manner as to give a permanently tight joint.

While the pipe is being laid it is to be blocked temporarily upon the caps by wooden wedges and after the pipe is aligned and graded and the joints poured and calked it will be concreted as shown upon the plans.

57. CONCRETE COVERING. The general specifications already given govern the concrete to be placed around the cast iron pipe. The pipe is to receive a 6" covering of concrete as shown in the cross-section of the siphon barrel on Plate V. as a protective covering.

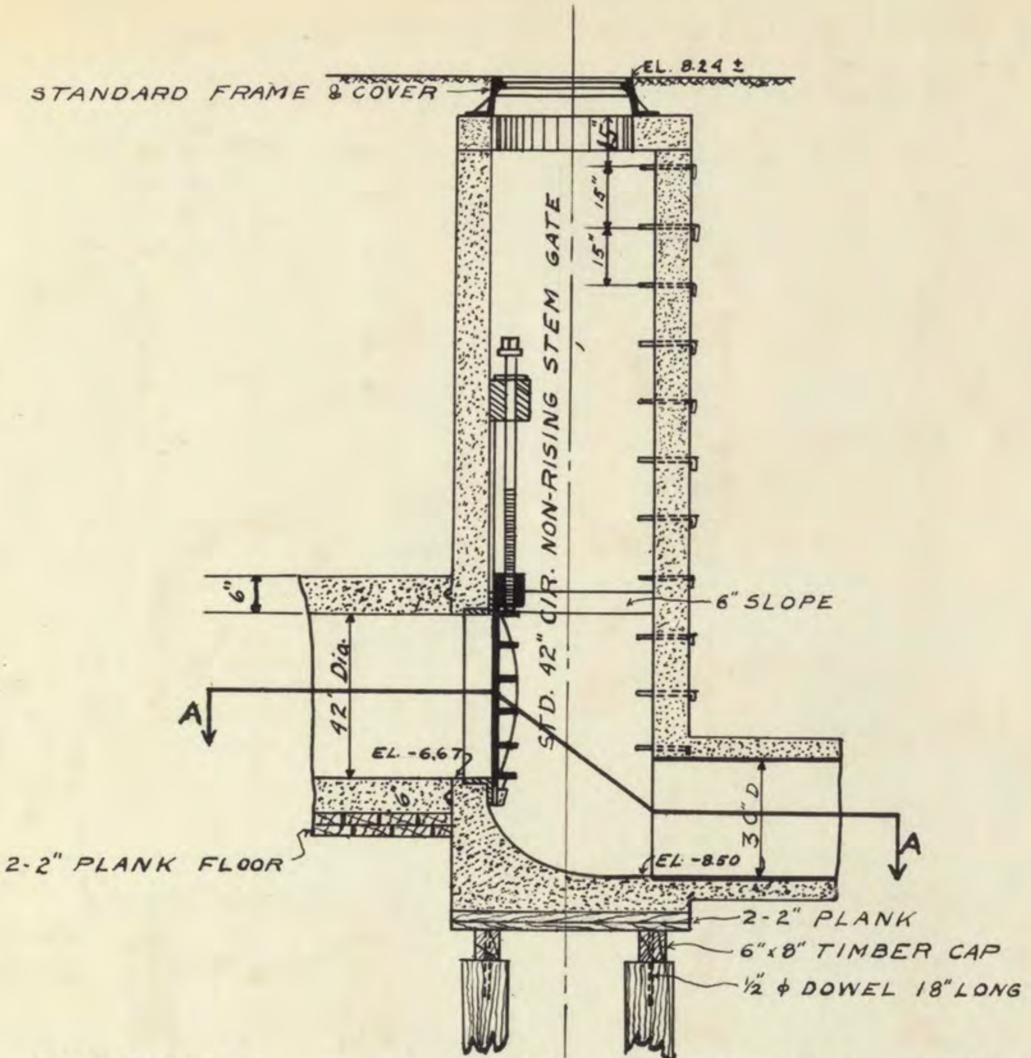
As yet no plans have been suggested for a concrete plant but undoubtedly the mixer will be set up south of the tracks under the 27th St., Viaduct and the concrete carried in a small car running on a track supported on the coffer-dam. Or it may be possible that a tower and spouting system will be used. The sewerage commission has given permission to spout any concrete directly into the forms, whenever the concrete does not form the sewer barrel proper but acts only as a protective covering. Of course the concrete must be well tamped and spaded so that it completely surrounds the pipe.

58. BACKFILLING AND PULLING SHEETING. The material that was placed on the outside of the sheeting, as it was excavated, will be picked up by the clam-shell bucket and backfilled around the concrete until the concrete is entirely covered. The material being wet will require no tamping.

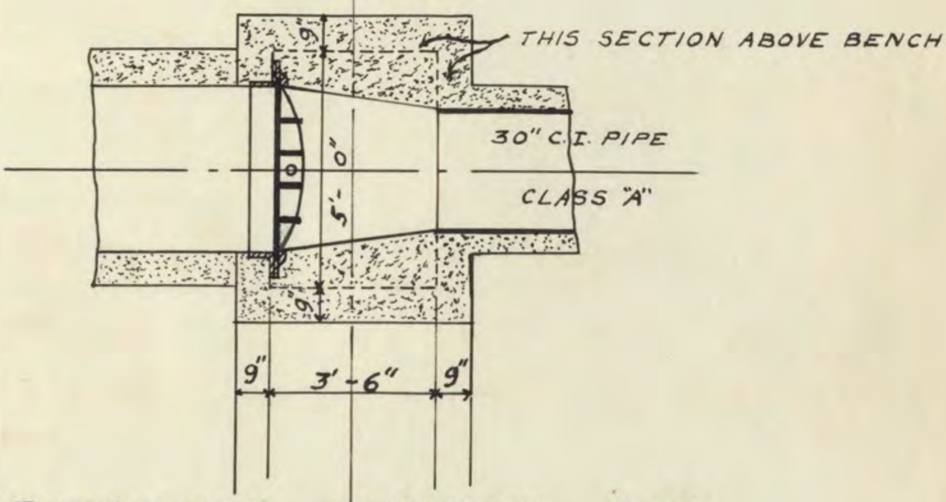
The steel sheeting will be pulled by the puller, using the falsework piles and the coffer dam as support. As the sheeting is pulled the action of the water will complete the backfilling over the siphon and any excess material that obstructs the stream channel will be excavated and disposed of on the land dump.

59. DROP AND RISER SHAFTS. The details of the drop and riser shafts of the siphon are shown on Plates VI and VII. These shafts are considered a part of the siphon and are included together with

PLATE VI.

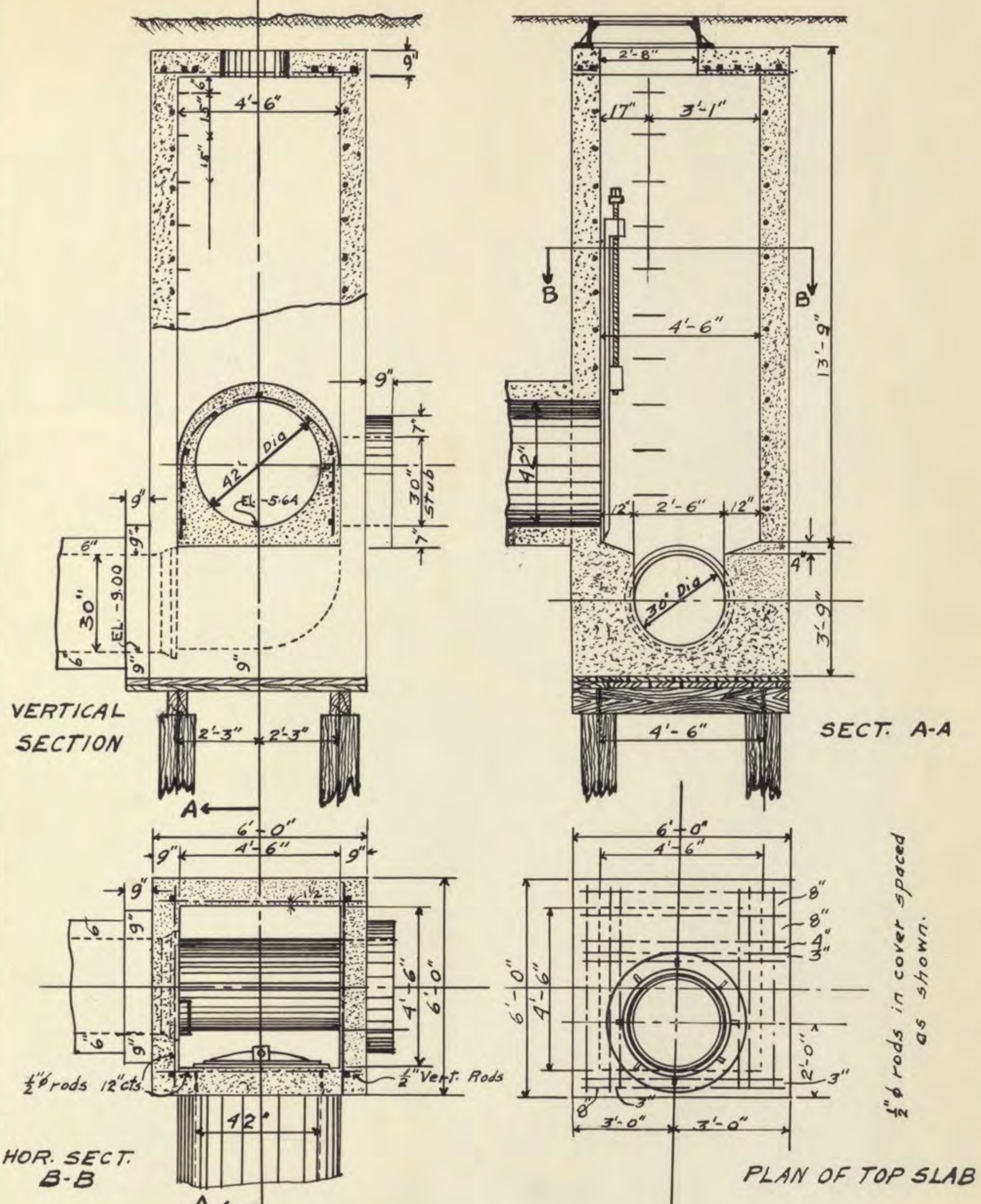


VERTICAL SECTION OF RISER SHAFT OF SIPHON



HORIZONTAL SECTION A-A

PLATE VII



DETAIL OF THE SIPHON DROP SHAFT

all their mechanical appurtenances in the unit price bid for the construction of the siphon.

The foundations for the siphon shafts differ but little from those used under the 48" and 42" concrete sewers. The piling under the riser shaft are spaced 3'-6" center to center and under the drop shaft, 4'-6" in both directions.

The shafts will both be built of concrete, both top slabs and the walls of the drop shaft being reinforced as shown in the Plate VII. Special forms will be required because neither shaft is of such dimensions as to permit the use of the standard manhole forms.

The siphon itself is designed to be self cleansing, having a grade of 0.23% but for some years yet to come until the maximum velocity is approached, sediment will undoubtedly collect in the barrel. It will therefore be necessary to clean it at intervals. The shafts have therefore been equipped with nonrising stem, sluice gates so that the flow of sewage can be stopped, the siphon pumped out and cleaned. The gates are to be furnished and placed by the contractor.

The standard manhole frame and cover previously described and shown on Plate III, is to be used for both drop and riser shafts.

The inside surfaces of the concrete shafts will be required to be finished in a workmanlike manner painting with a cement wash and filling all honey combed spots with a cement mortar.

G. TERRA COTTA PIPE SEWERS.

60..SPECIFICATIONS. (a) General. All terra cotta straight pipes used upon the work shall be furnished in two and one-half or three feet lengths, and shall be what is known as "standard strength" Each pipe must be composed of the best quality of clay or shale, vitrified throughout, perfectly burned, without cracks, blisters, pimples or other imperfections which, in the opinion of the Chief Engineer, may be harmful to its strength of durability . Each pipe must have a clear ring when sounded with a hammer. The diameter of any pipe must not vary from a true circle more than three-quarters of an inch, and must be truly straight. The hub and spigot must be cut off at right angles to the axis of the pipe so that the spigot can butt up to the shoulder of the hub and make good contact all around. The annular joint space shall be uniform and of ample size to get good joint. Each pipe must be well salt glazed over its entire surface. It is the intent of these specifications to describe the best standard terra cotta pipe which the market affords and the Chief Engineer will insist upon a strict compliance therewith

(b) Laying Pipe. The bell end of all pipe shall be laid up grade. Into the bell the spigot end shall be inserted until the face of the spigot comes into contact with the shoulder of the pipe all around. This spigot end shall be supported with sufficient jute or hemp to make the flow lines of the two pipes coincide at the joint. The pipe shall be laid at an accurate line and grade as given by the inspector and substantially blocked up to such line and grade. The joint shall then be well caulked with hemp or jute with a proper tool by an experienced workman; care being taken that no hemp or jute is allowed to project inside the pipe. The balance of the joint will then be thoroughly filled with cement mortar. After the pipes are thus laid and supported they will be enveloped with concrete of the thickness shown upon the plans. The concrete being placed in forms set prior to the laying of the pipe, and which must be removed as soon as the concrete has set. The coarse aggregate forming the concrete for the terra cotta pipe envelope should be finer than that used in the concrete forming other parts of the work. Care must be observed in placing the concrete around the pipe that the line and grade of the pipe is not disturbed during the operation.

None but competent pipe layers will be permitted to lay pipe, and the gang of men employed in laying, concreting and backfilling will be under the immediate supervision of the inspector who shall be given full authority to direct them while engaged upon this special work.

The ends of all pipes must be protected from the entrance of earth, or other materials, by means of a tapered wooden plug inserted in the bell ends, and this plug must be kept in the end of each pipe sewer when the pipe is not being laid continuously. The inside of the sewer must be kept free of all substances by means approved by the Chief Engineer. Each section of pipe sewer must be laid continuously between manholes. No jumping will be permitted from any cause.

61. 24 INCH TERRA COTTA PIPE SEWER ON NORTH CANAL ST.

(a) Preliminary Preparations. The contractor started work on North Canal St., the latter part of August 1916. He started by digging test pits that were carried to a depth of about ten feet so as to be sure that any underground structures that might be in the street would be located. The records showed no conduits from 13th to 15th Street, except an electric cable on the north side of the street, and the records were verified by the test pit results. Nothing whatever was encountered except the electric conduit.

(b) Alignment. The original line of the 24" sewer as located was to be 10 feet south of the north curb line of Canal St, so as to just clear the electric conduit mentioned above.

There is a team track belonging to the C. M. &. St. P.Ry.Co. paralleling No. Canal St., from 13th to 15th St., and the teams use about ½ of the street while loading and unloading freight. This track was not shown on the survey and was therefore not considered in the location of the new sewer. Although the track could have been arbitrarily closed, it was not deemed advisable, so the sewer was shifted to the south side of the street 7-½ feet from the curb line, leaving the team track open for service.

There is a line of electric service poles along the south curb of So. Canal St., that occupy about 1-½ feet of space; the trenching machine used required a clearance of 5 feet from the center of the trench; this left a space of one foot between the outside of the machine and the poles and half of the 25 feet street remained open to traffic, with the center line located as stated.

The line as originally located and the new line just described are shown in Figure XI. The new line in yellow was at first to extend to 18th St., following the dotted yellow line, but the large sewer from 15th to 16th was not located in the center of the street as assummed, so that other changes were made necessary. The changes made and the location of the old sewer as it was found to have been built are indicated in Figure XI and will be discussed in article 61 (I).

(c) Excavation. As soon as the center line of the sewer had been determined definitely, the paving blocks were removed for a width of four feet, for a distance of about 400 feet. The paving had been laid on a gravel base so it was easy to remove. The blocks were piled just outside the curb line on the walk,(the walk is little used) so that they would be convenient when ready to be replaced.

A sump was dug by hand at the east end of the sewer, at Muskego Avenue. The ground encountered was very good and stood up well without sheeting, and contained very little water. The bottom being solid, it was decided to omit the foundation piling and the underdrain and use the "firm earth section" shown on Plate I. The underdrain was omitted because in placing it, the ground would have been disturbed and the foundation softened; and as very little water accumulated, an underdrain was deemed a useless expense.

A Parson's, ladder type trenching machine was used on the entire ditch. This machine is equipped with an oscillating mechanism and is capable of digging a trench 72" wide. The trench for the 24" sewer was opened 4 feet wide. In excavating the machine was never permitted to dig down to grade, but the bottom was always left about 2 inches high and then trimmed down by hand so as to be sure and have a solid footing.

The material encountered was a comparatively dry sandy clay and as stated, stood up very well without any bracing. This being true, a skeleton bracing, that is two wooden sheeting every 5 feet, was thought to be sufficient. This was put in, back of the machine and seemed to be allright at first, but as the trench stood open over night the water drained toward the ditch and it was only a short time until all the sandy material had caved in, leaving the trench in a very bad and unsightly condition. It was at first thought that this was only a local condition but such was not the case and it soon became apparent that the entire trench would have to be close sheathed. Close sheeting was therefore used on all the rest of the trench.

The sheeting used was a hard maple material, 2"x8" and in 12 and 16 feet lengths. The sheeting was set in place as close to the machine as possible so as to prevent any cave-ins that were found to occur if this was not done. The rangers used were 3"x12" hard pine planks held in place by 2" pipe, trench jacks. At first three sets of jacks were used but as the depth of the trench decreased two braces were found to be sufficient.

All the excavated material not used for backfilling was hauled away to a land dump close at hand. The trenching machine is equipped with a belt conveyor for loading wagons.

No obstructions except two water mains(hydrant connections), two small sewer connections and three conduits were encountered during all of the excavating. This is a condition that would not be met with on very many of the city streets. The sewers were cut out and later replaced and the conduits were supported by hanging them to a timber across the trench. The water mains did not require any attention except care to avoid breaking while excavating near them with picks.

(d) Foundation. As previously stated the firm earth section of sewer is the one that was decided on to be used. The detail in Plate I shows a double 2" plank foundation for this section and arrangements were made to use plank but later changed. The contractor was given the alternative of using either a 3" concrete floor or the double plank floor and chose the former. The cost of the floors is about the same 22 cents plus or minus per foot of sewer. Payment was made for a depth of 3 inches and a width of 3 feet of concrete, as extra concrete at $8.00 per cubic yard.

If the bottom became mucky before the concrete was placed the contractor was required to clean out the muck and fill in with concrete at his own expense. To avoid this the concrete floor was always laid as soon as the excavation was complete.

The specifications already given for concrete etc., applied to the materials used for the floor. The concrete was mixed by a small steam "Koehring" mixer and hauled in wheel barrows to the trench. It was dumped into a steel hopper with an elephant trunk chute attached and spouted to the bottom of the trench. A man in the bottom of the ditch leveled off the concrete to the proper grade being very careful not to get any mud or dirty water mixed with the concrete. The material was dumped from the east to the west, forcing any water or muck ahead of the concrete to a sump dug at the end of the day's work, from whence the water was pumped out by a gasoline diaphragm pump.

The grade for the floor was obtained from the grade battens set at 25 feet intervals. Stakes or boat spikes were driven in the bottom of the trench to the proper grades and the concrete leveled to the tops of these stakes, giving a perfect grade to the top of the floor.

This concrete floor gives a good solid surface on which to lay the terra cotta pipe. After the pipe has been laid, there is no chance for any settlement whatever, and in the writer's opinion far surpasses a plank foundation in every respect.

The floor must set for at least 24 hours before any pipes are allowed to be laid on it and no walking around on it be permitted until the concrete has thoroughly hardened.

(e) Pipe Laying. The terra cotta pipe were lowered into the trench by a three legged movable derrick using a rope sling through the pipe so that the pipe could not possibly be dropped. Just before they were lowered the inspector sounded the pipe with a hammer and if they did not give a clear ring, which is an indication of a crack, the pipe was rejected. The pipes were all tested in this way as they were brought to the street and all rejected pipes were immediately hauled away, but very often a pipe is broken, while being rolled to the derrick, therefore the inspection just before being lowered into the ditch.

In laying the pipe the specifications were strictly adhered to. The jute packing was laid in the bell of the pipe already in position, then the spigot of the next pipe was inserted and brought up to make the flow lines level, by calking the jute properly under the pipe. The bell end of the pipe rested on two bricks laid on edge side by side and just back of the bell; two wedges, one on either side, were used on top of the bricks to bring the pipe to the true grade and line. After this had been done the packing was carefully calked into the joint all around, leaving a space of about one inch or more for the cement joint.

The mortar used in the joints was a 1:1 mixture although the specifications permit at 1:2-½. This mixture was found to work the best and easiest in cementing the joints, so it was used entirely. The joints were not cemented until several pipes had been laid ahead, so that the mortar would not be disturbed by any movement of the pipes. The mortar was placed in the joints by hand by an experienced laborer equipped with rubber gloves. Careful inspection being required to see that the mortar was forced into the joints thoroughly. Any small cracks occuring between the pipes, on the inside were cemented after the joint had been calked.

VEIW OF TRENCH ON NORTH CANAL ST.

PULLING SHEETING

After the pipes had been laid and the joints cemented a 2"x8" plank was laid lengthwise on top of the bells of the pipes and blocked down by struts to the lowest set of trench jacks. This bracing down was necessary to keep the pipes from heaving when the concrete was poured around them.

(f) Concrete Envelope. In some instances where the trench was too wide, a rough back form was built in order to save concrete but in most cases the sheeting was covered with a layer of tar paper and the concrete poured directly against this. The tar paper was used so that when the sheeting was withdrawn there would be no danger of injuring the concrete envelope by having it adhere to the sheeting.

The aggregates used in mixing the concrete for the envelope were the same as have been previously described except that the stone was finer, all of it passing a ½" ring. This gave a good "flowing" concrete and by a little tamping and spading it thoroughly enveloped the entire pipe when the covering was being poured. The same "Koehring" mixer aforementioned was used with wheel barrows conveying the concrete to the ditch. The mixer was set up five times for the sewer on NO. Canal St., so that at no time did the concrete aggregates have a chance to separate as the mixture was wheeled away from the mixer. This is sure to happen if the concrete is wheeled for any distance over a rough runway.

The concrete around the pipe was placed in two lifts, first bringing it up very near to the top of the pipe; then the braces were removed and the second lift of concrete poured so that there was a minimum of 4 inches over the top of the barrel of the pipe.

(g) The backfilling was placed the day after the envelope was poured, and was thoroughly tamped. Very often the excavated material was wet enough so that it needed no tamping. This is very desirable since it saves considerable labor. The bracing was removed as the backfilling progressed, and the sheeting pulled, if needed as soon as the backfilling was completed.

The original idea of the contractor was to pull the sheeting by hand. He rigged up a long lever with the pulling clamp attached to one end and attempted to follow out his idea, but it did not prove a success. Some of the sheeting he could not even start and a great deal of it pulled exceedingly hard. The hand method was abandoned and a puller built consisting of two A frames of 6"x6" timbers with a cross beam at their tops, and the whole properly cross braced. To the top cross beam was attached a three sheave steel block, with a double sheave block below to which was attached the pulling clamp. A snatch block was fastened to the sheeting and the ½" cable passed through this to the team of horses that furnished the pulling power.

With this arrangement the sheeting pulled very easily. Manned by three laborers and with a team and a driver, it was possible to pull the sheeting from both sides of 100 feet of ditch in ten hours. The wood piling were piled on top of the backfill until needed ahead. They were then loaded and hauled up to the excavating machine ready for use. Since it was not necessary to drive the sheeting, to any great extent, it was injured but little and was used again and again with slight loss.

(h) Repaving. The paving removed on No. Canal St., as has already been related was granite blocks laid on an 8 inch, very solid gravel base. This street has a very heavy traffic due to the team track and west of 15th St., there is a continual string of coal wagons and auto trucks from the coal docks. The trench necessarily had to be tamped very carefully so as not to obstruct this traffic for too long a time and if consistent the pavement would have been relaid immediately, but this was not done. The small piece that was removed on Muskego Avenue was replaced in December and has stood up remarkably well, no settlement being apparent. The remainder of the blocks will be relaid on a gravel base as soon as the frost is out of the ground, probably sometime in April.

(I) Special Crossing at 15th Street. Mention has previously been made of a special crossing at 15th St., and No. Canal. By referring to Figure XI some idea may be had of what was done.

As already stated in article 61 (b) the large 6"x4" sewer in North Canal Street had not been built in the center of the street as was originally assumed. A survey was made on the inside of the sewer and a proper location platted on the map. The original assumed location in Figure XI. is indicated by the white dotted lines; the actual location giving the sewer walls, has been platted in red.

East of 15th Street the changed location of the center line is shown by the full yellow line, and this was planned to extend West as shown by the dotted yellow line. After the sewer had been properly located it was evident that this could not be done so the change had to be made, and the center line established as shown by the full yellow line.

The large sewer coming down 15th Street is a 11'x4' brick sewer with a plank floor, placed on a timber pile foundation; the 6'x4' sewer running west is a concrete sewer. These sewers both are below datum at this point, having a flow line elevation of minus 1.30, and with the ordinary flow of sewage, were at all times filled nearly half full. The center line as shown first crosses the brick sewer and then the concrete sewer.

In building the 24" sewer, two dams made of sacked sand were placed at (A) Figure XI., on either side of the sewer. A hole was cut through the roof of the sewer and the sacks handled through this hole. The north dam diverted the sewage flow to the west into the 6'x4' concrete sewer, and the south dam kept out the river back water.

After these dams had been placed, part of the side walls of the large sewer and theplank floor together with the timber caps and piling were removed so as to permit placing the terra cotta pipe. The top outside of the concrete envelope of the new sewer was to be about 2 inches above the flow line of the old sewer. The excavation was made, the concrete floor laid, (this was increased in thickness from 3" to 6" under the large sewer), the pipe laid to grade and concreted and the walls of the sewer repaired with the dams holding perfectly. No trouble whatever occurred and the sewer was successfully completed up to the 6'x4' concrete sewer in a short time.

The sacks were removed from the 11'x4' sewer and the dams (B) built in the 6'x4' concrete sewer. The same method of construction as just described was carried out for the pipe under this sewer but a great deal of trouble was experience. For some reason or other the sewage, when diverted from the smaller sewer did not reach the river fast enough. It may have been that the large sewer was nearly stopped up, somewhere between No. Canal St., and the Menomonee River. At any rate the bottom had just been excavated ready for the concrete floor when the east dam gave way, inundating the entire work and filling the completed pipe with sewage.

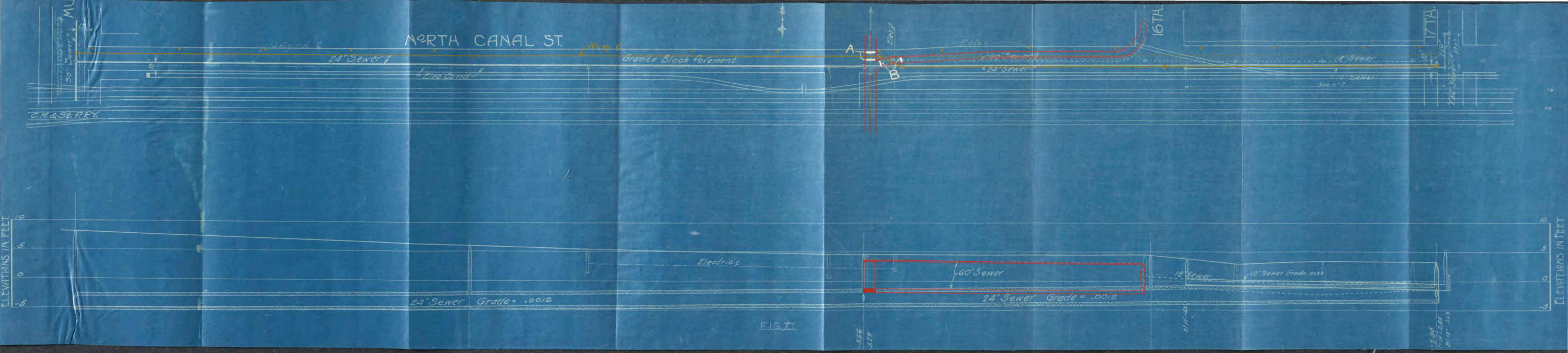

NoRTH CANAL ST.
24" Sewer
Granite Block Pavement
Elec Cond
C.M.&St.P.RY.
A
B
16TH.
17TH.
Poles
60" Sewer
24" Sewer
18" Sewer
12" Sewer
ELEVATIONS IN FEET
10
5
0
-5
Electric
60" Sewer
18" Sewer
12" Sewer Grade .0033
24" Sewer Grade = .0012
24" Sewer Grade = .0012

FIG XI

The dams were rebuilt and strengthened and the work again attempted. This time the floor had just been laid when the dams again broke. A third time they were rebuilt and the pipe laying and concreting prosecuted continuously, into the night until everything was completed. Sometime during the night the dams broke again but this time without any damage since all the work was finished and in a safe condition.

Had the large sewer not been obstructed as it undoubtedly was, this method of procedure would have been ideal, but such things are continually encountered and have to be expected and taken care of in the best manner.

One point that should be brought out by the foregoing discussion is "THOROUGH PRELIMINARY INVESTIGATION." Had the sewers been properly located originally, a great deal of expense and trouble could have been saved. Likewise the large sewer in fact both sewers should have been examined, so as to have been sure that they were free of any obstructions. Had this been done and the trouble removed from the large sewer, the breaking of the dams would never have occurred. The factor of preliminary investigations cannot be emphasized too strongly.

62. **THE 24 INCH SEWER IN ST. PAUL AVENUE.** The sewer in St. Paul Avenue is a 24" terra cotta pipe running from Tenth St., west, connecting with the 30" sewer in 13th St. The detail plan and profile showing the new sewer, in a part of St. Paul Avenue, are shown on a preceding figure under the article on "Topographic and Underground Data"

Although no work has as yet been started on this sewer the same plan of construction in general as has been described in the preceding article for the North Canal St., sewer, will be followed. There are more obstructions in this street than on any other one in the entire territory of Section No. 2 of the Menomonee Sewer. Every kind of underground structure found in any of the streets in Milwaukee are found in St. Paul Avenue. Due care will have to be exercised to protect these structures, as the work is carried on.

The excavation will be made with the Parson's Trenching Machine, but equipped with a larger "wheel" than was used on No. Canal St. The average depth of trench on Canal St., was about 10 feet, whereas the average on St. Paul Avenue will be approximately 16 feet. It is expected that good material will be encountered and that no foundation piling will be required. The concrete floor already described in article 61 will be substituted for the plank floor. No underdrain will be used unless the ground water proves excessive and the method used on No. Canal St., will not take care of it.

The paving block on St. Paul Avenue are laid on a concrete base, which will require considerable more labor to remove than the gravel base on No. Canal St., and of course when thepavement is replaced, a new concrete base will have to be built which means another added expense.

There are several large industrial plants on the south side of St. Paul Avenue, and their only entrance for teams is from the Avenue. Where driveways occur it is probable that the pavement will not be disturbed but that the pipe will be laid in a tunnel driven under the drives, so as not to interfere with the traffic any more than is absolutely necessary.

At 12th Street the new sewer will pass directly through the old Menomonee Intercepting Sewer in St. Paul Avenue., (refer to the attached map) but as this old sewer has never been of any service, no trouble is expected. This old interceptor was built with the intention of taking the dry weather flow from the large 48" sewer coming down 10th St., but through some error in design, it was not built low enough and the intercepting device was never installed. Since this is true, it is very probable that when the new sewer is built, the old manholes on either side of 12th St., will be filled up and the section of old sewer in between pumped out so that the new sewer may be built without any trouble from the back water flow that would come from the main 54" intercepting sewer in 13th St.

This new 24" sewer is to pass under the old 54" sewer at the corner of 13th St., and St. Paul Avenue and some trouble may be encountered when this construction is attempted. The section under the sewer is to be of cast iron a detail drawing of which is given on Plate III. The method of construction proposed for this crossing has already been given under the article on "Special Investigation,"so no further discussion of the subject will be given at this time.

63. THE 15 INCH SEWER. As already related in detail under a previous article, the line of sewer connecting with the 24" sewer just described in article 61, was to have been a 12" terra cotta pipe sewer extending east as far as 7th St., and Hill Place. The size and grade of the sewer was changed to a 15" terra cotta pipe for reasons already explained.

The 15" sewer extends from the east end of the 24" sewer at 10th St., up St. Paul Avenue, passing under the old 48" sewer coming down 10th St., to the alley just west of 8th St; thence south in this alley to Hinman St., and east on Hinman to 8th St. Contrary to the usual rule, the flow lines instead of the haunches of the 15" and 24" sewers, are made level where the sewers join. This was necessary in order to get clearance enough to pass under the old 48" sewer with the 15" pipe.

The average excavation in St. Paul Avenue, is only 14 feet so a trenching machine will be used. The average depth from St. Paul Avenue to 8th St., is about 9 feet and although a machine would handle this depth very economically the alley and Hinman St., are too narrow to successfully use the machine in, so that this part of the line, about 500 feet, will be excavated by hand. This hand work will be started before the 1st of April and the remainder of the line on St. Paul Avenue will be built after the 24" has been completed.

It should be stated that all the pipe both the 15" and the 24" is now on the street ready to be laid as soon as the weather permits. Plans were made to do this terra cotta pipe sewer work during the winter, but on account of the extreme cold and the amount of snow that fell, the work could not have been carried on successfully or economically. With the pipe on the ground and weather conditions permitting this line of sewers should be completed by or before July 1st 1917.

H. RECORDS AND REPORTS.

64. GENERAL. A very careful record is kept of all the work done by the contractor and by the engineering department. Several reports are made out each day and properly disposed of. These records and reports will be taken up in detail so as to give the reader a fair knowledge as to how this part of the work is handled.

65. LEVEL BOOKS. In the level book, an ordinary field note book, a record of all the level notes are made. Check bench mark elevations, scale elevations, curbing and sidewalk elevations are all recorded therein. All grade elevations or other elevations used in connection with the actual construction work, are carefully recorded, so that should any question arise regarding any of them, either on the work, in court or otherwise, the notes and figures could easily be checked.

66. TRANSIT BOOK. The transit book is used for recording all surveys that are made, including surveys for changes of line and all special investigations made such as have already been described. A record of the center lines of the sewers as established in the field is kept and all points used are carefully sketched and properly referenced so that they can easily be found and the line so relocated at a moments notice.

67. INSPECTOR'S REPORTS. The engineer inspector renders a daily report to the resident engineer. This report is made out in triplicate and contains a record of all the work accomplished, materials used and progress of the work for that date. A report of all the labor is also made so that the labor cost for any part of the work for any day, may be determined. The original and duplicate of this report is submitted to the resident engineer and the triplicate is retained by the inspector for his own records and reference. The engineer checks therreports and sends the original to the principle assistant engineer retaining the duplicate for his own file.

The inspector likewise keeps a graphic record of the daily progress of each part of the construction. These records are called progress curves and are not required by the sewerage commission but are made out by the writer's inspectors as a convenient reference record. A sample progress curve sheet is found on the following page. By reference to this it is seen, how the progress for any day week or the entire month, on any part of the work can easily be read at a glance. By the aid of these curves the engineer in the office, should the progress not appear regular enough as determined from the curves, can inquire from his inspector as to the probable cause or can go out on the works knowing just what he should give the most attention so as to get better results.

These curves are filed in a book as soon as they are completed for the month and thus a comparison of the work accomplished can readily be made with that of any other month preceding.

The inspector keeps a pocket note book with a complete daily record of all the information given in his reports. This is for his own convenience and use on the works.

68. ENGINEER'S REPORTS. (a) Men employed. The resident engineer is required to report daily to the principle assistant engineer, all the men employed under his direction and what they are doing.

(b) Extra Work. Should any work be done by the contractor classed as "extra work," the engineer must render a daily report of all labor and materials used by the contractor. Each extra work order is lettered and the reports are lettered to correspond to the order. Should more than one day be required to do the work, the reports are numbered, in addition to the letter and the last report is marked final, showing that the work on the particular extra work order, has been finished.

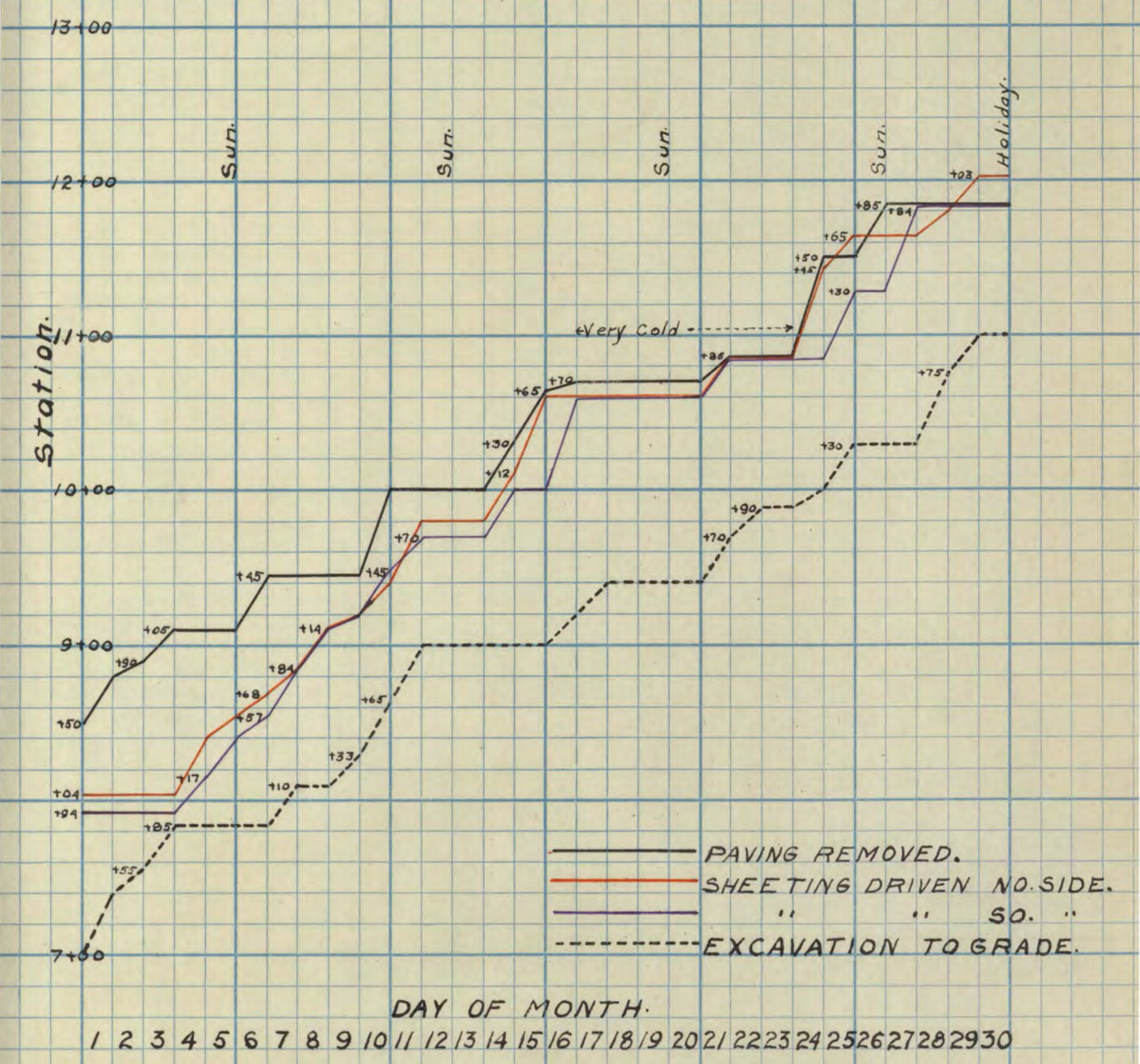
PROGRESS CURVES FOR:- Paving Removed, Sheeting Driven, and Excavation to Grade, for 48" Sewer. ACC. NO. 88

SHEET

COMPUTED BY R.W.G. CHECKED BY R.A.L. DATE November 1916

MADE IN CONNECTION WITH The Menomonee Valley Low Level Sewer, on South Canal Street.

NOTE:- Similar curves are made out for the progress on:- Piling driven and flooring laid; concrete invert, concrete arch, and backfilling.



(c) Obstructions. Obstructions of any nature that might in any way interfere with the work are reported on a special form with a recommendation, to the principal assistant engineer, as to what should be done in the particular case. These reports are made out, if possible, long before the actual obstruction is encountered, so that plenty of time is available to do whatever work is required.

(d) Labor Distribution. A record of all labor is made daily on a report made out by the resident engineer. On this report the charges are distributed by labor hours according to the items given on the distribution sheet on the following page. This report is made up from the information and records contained on the inspector's daily report mentioned before. A sample of this report filled out for an ordinary day's work is inserted here for convenience. This form of daily labor distribution report is made up standard so that it can be used on all of the sewer work of the commission whether it be in tunnel or open cut.

The original of the labor report is sent to the principal assistant engineer's office where the information is transferred to a monthly sheet very similar except for size to the daily report sheet. All the reports mentioned above are made out in duplicate, one copy being sent to the principal assistant engineer for filing and the other is kept by the resident engineer in his own files.

(e) Stub Connections. A book containing a record of all the stub connections, whether in the manholes or in the line of sewers is kept by the resident engineer. The advantage of this is obvious when you consider the time and trouble that would be spent searching for connections that were not definitely located.

This is a feature that should be strongly emphasized in all sewer construction.

The method used in locating the stubs, is to give their station number and plus, along the line of the sewer, the distance from a given manhole and the location with respect to some permanent line, such as a curb line, fence line or building line. There position in the sewer is also give, whether at the crown of the arch or the springing line, or at whatever degree and to what side of the center line the connection is turned.

(f) Underground Structures. In carrying out the work of sewer construction in open cutting, innumerable underground structures are encountered. At times these are injured during the opening of the trench or while the sheet piling is being driven. The structure is then easily repaired before the trench is backfilled, but more often the trouble occurs after the backfill is in place, due to the fact that it settles a great deal, breaking the pipes and conduits. A complete record of the services encountered is therefore kept so that they can easily be located again. The records contain a sketch showing the direction and location of the structure with reference to the line of the sewer, what size it is, whether it be a water or gas pipe or an electric conduit, and the depth below the ground at which it was encountered. The condition at the time it was struck and at the time the trench was backfilled is also given, so that the blame can be placed on the proper parties whether it be the city, contractor, or the owner of the structure.

LABOR DISTRIBUTION SHEET FOR SECTION NO.2 OF THE MENOMONEE VALLEY LOW LEVEL INTERCEPTING SEWER.

ITEM		LABOR PERFORMED ON
1		Sinking Shafts. All labor, mechanics & disposal of material.
2		Hauling & Erecting Plant & Equipment.
	A	Shaft Houses & Hoists.
	B	Excavating Machine. (State kind.)
	C	Pile Drivers & Pile Pullers.
	D	Pumps.
	E	Lighting Plant.
	F	Concrete Plant
		For dismantling use sub 1; For repairs use sub 2.
3		Excavating, Bracing & disposal of Material.
	A	30" Cast Iron Pipe Inverted Pressure Siphon.
	B	48" Reinforced Concrete Sewer.
	C	42" " " "
	D	30" " " "
	E	24" Terra Cotta Pipe Sewer In Tunnel.
	F	24" " " " " " Open Cut.
	G	12" " " " " " Tunnel.
	H	12" " " " " ")pen Cut.
		Use sub 1 for scow disposal: sub 2 for disposal to land dump.
4		Concrete. Mixing, Placing, Forms and Formwork, and Hauling.
	A	30" Cast Iron Pipe Siphon. (To include calking.)
	AA	Concrete Around the 30" CastIron Pipe Siphon.
	B	48" Reinforced Concrete Sewer.
	C	42" " " "
	D	30" " " "
	E	24" Terra Cotta Pipe Sewer in Tunnel.
	F	24" " " " " " Open Cut.
	G	12" " " " " " Tunnel.
	H	12" " " " " " Open Cut.
		Use sub 1 for hauling concrete materials; sub 2, hauling pipe.
5	A	Steel Sheet Piling. (Driving, Pulling & Moving.)
	B	Wood Sheet Piling. " " "
	C	Foundation Piling. (Driving & Cutting Off.)
	D	Timber Caps. (Cutting and Placing.)
	E	Plank Floor.
	F	Underdrain.
	G	Steel Reinforcement. (Handling and Placing.)
6	A	Repairing Subgrade and Paving Foundation.
	B	Repaving. Give the type of pavement.
	C	Remaoving Pavement.
7	A	Brick Manholes. Give location.
	B	Concrete Manholes. (Location.)
		Use sub 1 for hauling materials.
8	A	Watchman.
	B	Pumpman.
9		Relaying Conduits, Waterpipes, Gas Mains, Etc.
10		Force Account. Give discription and location of the work.

Sewerage Commission of the City of Milwaukee

Daily Labor-Material-Pay Quantity-Progress-Report

Contract No. 12 Date 11-1-16.

Labor

ITEMS	Res. Engineer	Superintendent	General Foreman	Foreman	Material Men	Hoist Engineer	Fireman	Master Mechanic	Mechanics	Electricians	Carpenters	Masons	Blacksmiths	Blacksmith Helper	Millmen	Miners	Muckers	Pumpmen	Watchmen	Water Boy	Labors Rate 30¢	Labors Rate 35¢	Handy Men	Truck Drivers	Teams	Trucks	Driver Men	Derrick Men	Crane Men	Pipe Layers	Pipe Tenders	Compressor Eng'n'r	Compressor Men	Lock Tenders	Shield Foreman	Shield Operators	Timekeeper	Storekeeper	Clerk
2 B						5	5																				10	Erecting shelter over engine on puller, & laying water pipe.											
3 B		5				22															69						5												
4 B		2		10																	10		Setting forms and concreting																
5 C		1		5		5	5																				15												
5 D		1		2																							8												
5 E		1		3																							12												
5 F		1																																					
5 G																					10																		
6 C																											10												
7 A												4									12																		
8 A																			24																				
Gen'l	10										10		10	10																							10		10
3 F						8	8														48	8			4														
4 F				11		5	3														30	33																	
4 F_1				2																					2														
3 F_2																									16														

Material and Pay Quantities / Progress

ITEMS	Lineal Feet	Cubic Yards	Method	Size	Width	Depth	Lineal Feet Ditch	B M Feet Timber	Bags Cement	Yards Sand	Yards Stone	Yards Gravel	Pounds Steel Reinf.	Brick	Sheathing Left in Place	Manhole F & Covers	Coal	Current	Oil	Shaft Number	Heading	From Station	To Station	Feet	Total to Date	Total to Do	Character of Ground
2 B																											
3 B		190			8'	16'	40															7+00	7+40	40	Excavated to grade.		
4 B	37	7.7		48					51	3.7	6.7		327									5+95	6+32	37	Arch Concreted		
5 C	194	Cut off.																				7+00	7+17	17	4 Piling Driven		
5 D								181														"	"	"	Timber caps		
5 E								374														"	"	"	Flooring		
5 F	17																					"	"	"	Underdrain		
5 G																											
6 C																						8+50	8+80	30	Paving removed		
7 A																											
8 A																											
Gen'l																											
3 F		38		24"	4'	11'	20															4+55	4+75	20	To grade.		
4 F	66	107							61	5.2	9.3											3+74	4+40	66			
		017 Cu.yds. extra concrete in manhole fdtn. 6'x6'																									
4 F_1		041							10	0.8	1.5											4+50	4+65	15	Conc. Floor as ext. conc		
3 F_2																											

(g) Progress Profiles. A map drawn on profile paper 20" wide, giving the street plan and the ground profile of the street forms the basis for the "Progress Profile." This is made up in the drafting room, using black ink.

As the work progresses, the resident engineer draws in the center line of the sewer as it is actually located, giving all the hub locations and their reference ties to permanent objects. Green ink on red line, and red ink on green lined paper is used for this purpose so that the center line location "stands out" from the rest of the plan. In addition, the adjacent buildings, platform scales, spur tracks, sidewalks, etc., are located and platted on the plan. Whenever a sub-structure is encountered it is platted, in the proper convention, giving the plus at its intersection with the sewer center line and indicating the direction at which it crosses the trench.

The sub-structures are also shown on the street "section," at their proper depth below the street surface, and a statement of the condition in which they are found and their condition when the backfill is made is recorded directly over them on the street section. If any trouble occurs after the backfill is placed, the structures are easily located, and theresponsibility for their condition determined.

A section of the sewer, at its proper elevation is platted on the street section, the kind of foundation is indicated and the underdrain, if there be any, is also shown.

As the work progresses, the amount of steel sheeting driven each day, is indicated by stationing. The excavation of each day is shown by a dotted line, and the total excavation for the month is in one color, a separate color with a proper legend being used for each month. The section of the sewer must not be colored for the excavation, as this is colored for the month showing the concrete arch and invert placed. The concrete placed each day is indicated by stationing as is also the foundation piling, caps, flooring and underdrain. The amount of piling remaining in the ground for each day's cut-off, between any two stations is also given. All the work done in any one month is colored with the proper color for that month. Backfilling for the month is indicated by a statement of stationing for each month.

The data is entered on this profile at the end of each week from the information given in the reports of the inspectors. On the first Thursday of each month this profile, with data complete to the first of the month, is sent to the main office and presented to the board of commissioners for their inspection. At a glance they can tell just what has been done on each separate contract and if they so desire they can make a comparison from the stationing of the work accomplished each day on any separate part of the work and be informed by the chief engineer on any questions they may have to ask.

A similar progress map for the terra cotta pipe sewers, giving excavation, floor laid, pipe laid, concrete envelope and backfilling is also made.

(h) Estimates. Monthly estimates for work completed are made out by the Principal Assistant Engineer from the data furnished sample Copy of the December Estimate

SEWERAGE COMMISSION OF THE
CITY OF MILWAUKEE
Estimate of JAMES KENNEDY

Contract No. 12 Estimate No. 4, For Month Ending DECEMBER 31st. 1916.

ESTIMATED QUANTITIES	ITEM	CLASS OF WORK	UNIT	QUANTITIES PREVIOUS ESTIMATE	THIS ESTIMATE	TOTAL TO DATE	PRICE	AMOUNT
1	1	30" C. I. Pipe Siphon	1	879'	227'	1106'	$12836.00	18802 00
2970	2	48" Reinforced Concrete Sewer	Lin. ft.				17.00	
5116	3	42" " " "	" "				15.00	
1850	4	30" Concrete Sewer	" "				13.10	
2610	5	24" Terra Cotta Pipe Sewer	" "	1037'	546'	1583'	9.00	14247 00
1406	6	12" " " " "	" "				7.00	
20	7	Drop Manhole	" "				7.00	
509	8	Std. "	" "	37'	26.25'	63.25'	6.00	379 50
37	9	C. I. Frames and Covers	Manhole	3	4	7	15.00	105 00
75800	10	Piles	Lin. ft.	9753'	2025'	11778'	0.40	4711 20
2.000	11	4"x4" Piles	1000 B.M. ft.				50.00	
214.000	12	Plank Foundation	1000 B.M. ft.	19.49M	4.95M	24.44M	30.00	733 20
106.200	13	Timber Caps	1000 B.M. ft.	9.47M	2.40M	11.87M	35.00	415 45
13000	14	Under-drain	Lin. ft.	886'	140'	1026'	0.50	513 00
		Brick Masonry	Cu. Yd.				15.00	
		Portland Concrete Masonry	Cu. Yd.	37.75	14.24	51,99	8.00	415 92
		Earth Excavation	Cu. Yd.				1.00	
		Steel Reinforcement	Ton				120.00	
		Sheathing or Bracing Left in Place	1000 B. M. ft.	.715M	0	.715M	20.00	14 30
		Rock Excavation	Cu. Yd.				3.00	

Total value of work to date	40 336 57
Less 25% retained	10 084 14
Balance	30 252 43
Less previous payments	22 589 74
Amount due on this estimate	7 662 69

(In words) SEVEN THOUSAND SIX HUNDRED SIXTY-TWO AND 69/100 DOLLARS

I hereby certify that the Material and Labor in above estimate are correct and payment on same is due contractor.

Jas. L. Ferebee
Principal Assistant Engineer

APPROVED

T. CHALKLEY HATTON
Chief Engineer

Prices, Footings and Extensions, and amount of previous estimates correct.

J. H. Fowles
Secretary of Sewerage Commission

by the resident engineer. This data is obtained from the daily labor reports and is checked with the progress profile and also by a special report that the writer uses. This report is a form on which all the daily records are entered, work performed, materials used etc., each in a separate column. The columns are totaled for each month and a copy of the report is sent to the main office the original being retained by the resident engineer.

The filled in form shown on the following page is a sample of the way the monthly estimates are made out. Four copies of these are made up by the principal assistant engineer's clerk; one is sent to the contractor, one to the resident engiheer, one to the secretary of the commission for his records and the other is filed in the principal assistant's office.

The final estimate, to which will be attached a certificate of acceptance, dated and signed by the Chief Engineer, stating that the work has been fully completed in compliance with the terms of the contract, specifications and plans, or authorized changes of the same, and to his entire satisfaction, will be filed with the Sewerage Commission and a copy furnished the Contractor within thirty days after the date of such certificate and acceptance. Within fifteen days thereafter the Sewerage Commission will give the Contractor an opportunity to file any objections he may have to such final estimate, all such objections to be filed in detail in writing so they may be considered by the Sewerage Commission, and within thirty days thereafter the whole amount shown upon such final estimate as accruing the Contractor, subject to such revision as the Sewerage Commission may determine upon under the authority conferred upon it by the terms of the contract, will be due and payable to the Contractor, provided,however,that there shall be retained from such final estimate, or from any payments due the Contractor under the contract all amounts which may be expended by the Sewerage Commission or City, for work done or materials furnished in carrying out any of the work done, which the Contractor has failed to do to the satisfaction of the Chief Engineer, and all amounts which it may be necessary to pay for labor, tools, plant and materials engaged and used upon the construction of the work any for which the Contractor has failed to pay, and all sums which the City is entitled to retain as liquidated damages in case the work is not completed within the time specified.

I. CONSTRUCTION RESUME.

As a conslusion to the foregoing discussion on construction, a brief statement of the status of the work, on March 1, 1917, being done on Section No. 2 of the Menomonee Valley Low Level Intercepting Sewer, which has been described as an example of the way the sewer construction work is being carried on under the direction of the Sewerage Commission of the City of Milwaukee, will be given:-

Of the 2970 lineal feet of 48" reinforced concrete there has been completed about 1200 feet leaving 1770 feet yet to be constructed. With a progress of 500 feet a month which is a very good average figure, this sewer should all be completed by the middle of July 1917.

No work has as yet been started on the 5116 lineal feet of 42" reinforced concrete sewer, but as now planned a new crew will be organized and the building of this sewer carried on simultaneously with the 48" sewer. At least 600 feet per month of this size sewer should be built, and at this rate the construction should be completed by January 1, 1918, if the work is started by May 1st. Everything possible will be done so as to accomplish this result.

1600 lineal feet of the 2610 feet of 24" sewer have been finished leaving 1000 feet yet to be built. At a conservative estimate this should be completed by June 1st 1917.

The 15" sewer will be started as soon as the 24" has been completed. There are 1000 feet of this to be built, 500 feet of which will be excavated for by hand and carried on at the same time with the 24 inch sewer. No unforseen conditions arising, the entire line from 13th St., to 8th St., along St. Paul Avenue, will be completed July 1st, 1917.

The crew after finishing the terra cotta pipe sewers will be started to work immediately on the 30" concrete sewer on 13th St., and on Muskego Avenue. There are 1100 lineal feet of this sewer and all will have to be built under rather adverse conditions. At a conservative estimate the sewer will not be finished before the latter part of October 1917.

The crew building the 48" concrete sewer after they have finished in July will start the construction of the 42" sewer on 27th St., and the 30" sewer on Greves St., There are 770 feet of 30" and 580 feet of 42" a total of 1350 feet. This amount could not possibly be completed in less than three months and due to interference by the railroad tracks it will undoubtedly take longer than this. December, 1st, is the date that has been set for the completion of this section of the contract.

The inverted pressure siphon under the river, the contract for which has been sublet, will be started sometime in May and it is planned to have it entirely completed by early fall 1917.

The 24" terra cotta pipe sewer on No. Canal St., 1600 feet, has already been completed.

In general the progress made by the contractor has been very unsatisfactory. The progress where crews have been working is very good, but the main trouble is due to the fact that the work is not being prosecuted at enough points. Pressure will be exerted early so as to compel the contractor to complete the entire contract by December 31st, 1916. Of course, there will remain, paving to be replaced, cleaning sewers, patching leaks, cleaning up debris etc., but the actual construction work will all have to be finished by the above date or the work will be completed by forces under the direction of the Commission's engineering department, and the cost of the same charged to the contractor or his bondsman.

RESUME

A brief resume of the conclusions reached, after two years of experimental work upon sewage disposal, is very appropriate. In forming the conclusions there are certain determining conditions connected with the Milwaukee situation, which are not common to all large municipalities, to-wit:-

The natural drainage of the present city and the area embraced within the anticipated limits of 1950 converge into one outlet, the harbor entrance.

The public water supply is secured, from Lake Michigan in 50 feet depth of water at a point located about 3½ miles from the harbor entrance. This condition requires a high standard effluent of uniform quality to be produced from a sewage treatment plant.

There is no constant current in any one direction in the lake. The velocity and direction are largely due to meterological conditions.

The only logical site for a sewerage disposal plant is on or near the lake shore and the only available ground is "Jones Island".

The natural island has for too small an area to locate a sewage disposal plant thereon and such plant must be built upon ground made out into the lake.

There is no low ground either in the City or its proximity suitable to the disposition of sludge; in fact, low ground is so scarce that those who are required to dispose waste materials pay for the privilege of filling in the low ground. Sludge could not be used to make up land into the lake, as it would cause a nuisance which would not be tolerated by the owners of the lake front, and might pollute the bathing beaches. It is considered inimical to public policy and to the future of the harbor, to deposit sewage sludge in the lake. It therefore appears necessary to either incinerate the sludge or reduce it to and dispose of it as a furtilizer.

Locating the disposal plant within the city limits, as is necessary, prohibits a sewage treatment process which produces objectionable odors or flies.

Chemical precipitation removed the solids in suspension to a satisfactory degree, but the effluent produced did not meet the stability requirements. The sludge produced was enormous, and its value was not sufficient to warrant the cost necessary to reduce it to a fertilizer. Its incineration would cost between $12.00 and $14.00, per million gallons of sewage treated.

Treatment by colloidar slate tanks gave a satisfactory effluent most of the time, but produced enormous quantities of sludge with low fertilizing value. The first cost of a colloidar slate tank plant would be prohibitory.

Fine screening, considered as a single process, would neither remove sufficient suspended matter to meet the requirements nor improve the stability of the sewage.

Electrolysis was both offensive and uncertain. It had to be augmented with lime treatment and produced large quantities of sludge which was unprofitable to reduce to a fertilizer. From the experiments carried out with this process, the operating charges would be prohibitory.

Sedimentation by Imhoff tanks reduced the suspended matter about 50% but produced a highly putrescible effluent. To satisfactorily sterilize this effluent required approximately 9 parts of chlorine, costing about $5.30 per million gallons. The sludge produced was not of sufficient value to warrant its reduction to a fertilizer, and to incinerate it would cost approximately $5.00 per million gallons of sewage treated.

Imhoff tank and sprinkling filters followed by final sedimentation produced a satisfactory effluent capable of being discharged into the lake without endangering the water supply. This treatment left the sludge to dispose of by incineration; cut out the sterilization, produced objectionable odors and flies, and required a prohibitory area of ground(over 80 acres)to be made up in the lake. The overhead charges for first cost of plant, under the existing conditions, add nearly $9.00 per million gallons to the cost of treatment by this process.

The activated sludge system if properly designed, built and operated, produces a clear, non-putrescible effluent with a reduction of at least 95% bacteria and 98% suspended matters, and a sludge of sufficient value to warrant its reduction to a fertilizer. Its operation is odorless and free from flies and it occupies a minimum area of ground.

On the other hand it requires constant and expert supervision for its successful operation and large operating cost for air and sludge disposal. Its cost, including all overhead operating and sludge disposal is estimated to be from $12.00 to $15.00 per million gallons, from which must be deducted such returns as may be obtained from the sale of the sludge, amounting to from $5.00 to $6.00 per million gallons, or a net cost of from $7.00 to $10.00 per million gallons of sewage treated.

Of all the processes experimented with the activated sludge appears to be the only one which fits the existing conditions in Milwaukee.

The maximum volume of air required to produce a stable effluent from which 95% of bacteria and 98% suspended solids have been removed, is 2 cubic feet per gallon of sewage, based on 10 feet effective head of sewage in the aerating tanks.

The maximum aerating period for both sewage and activated sludge is 4 hours.

The percentage of activated sludge in contact with the sewage may range from 15 to 25, without materially affecting results.

The sedimentation period required is from 40 to 50 minutes. The maximum horizontal velocity is 3 feet per minute and the vertical velocity , about 8 inches per minute. Uniform velocities must be maintained as far as possible.

The slopes for successfully removing sludge from the sedimentation tanks should be from 1 to 2, to 2 to 3, and it is preferable to remove the sludge through a down pipe built in the bottom of the sedimentation tank.

Breaking up the air in small bubbles increases the oxygen absorbed by the sewage in the aerating tanks, but sufficient air must be diffused through the sewage to rapidly disturb its entire volume and to maintain the solids in suspension. Baffles properly placed undoubtedly increase the efficiency of the tank.

Filtros plates satisfactorily diffuse the air. To maintain their efficiency they should be carefully made and placed, fairly uniform in porosity and all oil and dust should be excluded from the air passing to and through the plates.

Wood plates give smaller bubbles than filtros plates at less loss in pressure, but insufficient experiments have been carried out to warrant their adoption.

The sewage can be clarified in from one to one and one-half hours aeration in the presence of well activated sludge, by using ½ to 1 cubic foot of air per gallon in a 10 feet depth of tank, but the activity of the sludge cannot be maintained with out additional aeration.

If clarification alone was required, aerating the sludge 3 hours and the sewage one hour would produce the desired results.

Maintaining a sludge blanket near the surface of the sedimentation tank filters the floating matters from the liquor and produces a clear sparkling effluent, but this blanket is difficult to maintain, as it is quickly affected by temperature changes, variations of flow through and sludge from tank.

The aerating tanks can take care of storm water flow when designed to provide for average dry weather flow by increasing the volume of air and the activated sludge, but extra sedimentation area must be provided for storm flow if a standard effluent is to be maintained.

Conduits cannot be used to carry a mixture of sewage and activated sludge, because the sludge settles too quickly, even through velocities of 2 feet per second are maintained.

The activated sludge precipitated in the sedimentation tanks contains about 99% water. This may be reduced by subsequent settlement for from 1 to 3 hours to 96%.

Overaeration of sludge reduces its volume and its tendency to "flock," and decreases its specific gravity.

Sludge can be dewatered satisfactorily from 96% to 75% moisture by either a plate press or pressure press without the addition of lime or other base. The minimum cost of this process is still undetermined.

The filter bags used in the process must be cleaned frequently to maintain efficiency. This can be done by soaking in a bath of dilute caustic soda and hot water.

Sludge after pressing can be stored in a building without creating offensive odors more than 50 feet away, and can be easily handled.

The dewatering of sludge from 75% to 10% moisture can be satisfactorily accomplished by either the indirect steam or direct heat dryers, without appreciable loss of ammonia. The mimimum cost for this operation is yet to be determined.

Milwaukee sludge, after drying, contains from 4;5 to 5% of ammonia as a fertilizer. There is ample market for such a production when reduced to the proper form.

Estimating 4 hours aeration of sewage and 2 hours subsequent settlement of sludge, 8 million gallons of sewage can be treated upon one acre of ground.

Although there are many other conclusions of minor importance which have been reached from the experiments made, those enumerated are of the most importance in determining the design of the large plant.

It is now planned to build a 30,000,00 gallon disposal unit first and have it in operation by 1919. The sewage treated will be that handled by the low level sewers, (about ½ of the sewage now going into the lake and rivers) which will be running at their maximum capacity until the high level relief sewers are put in operation. The intercepting devices will be built and connected as soon as the plant is completed and ready for the sewage.

Immediately after completing the 30,000,000 gallon unit the plant will be increased to be ready about 1921, to care for the 1930 population and later to providedfor the ultimate 1950 population.

No more sewer contracts will be let until those now under construction are completed. All the attention will be turned to the new disposal plant with especial effort toward perfecting methods of reducing the excess sludge to a commercial fertilizer.

A tabulated report of the various costs and expenditures entailed by the work carried on by the Milwaukee Sewerage Commission is of interest. The table given below is not exact except for past years, but as a whole is a very close estimate.

Actual Expenditures to March 1, 1917.

Administrative, 1914, 15 and 16	166,749.90
Construction, 1914, (Testing Station etc.)	35,694.17
Experimental disposal unit and sewer construction completed and under contract 1915-'16-'17	3,102,274.72
Total	3,304,718.79

Estimated Expenditures to Complete the System

Contracted cost of sewers under construction	3,039,294.90
Engineering dept's. estimate for the same	2,537,695.92
Increase of actual cost over the estimated cost	501,598.88
Original estimated cost of sewers yet to be built	1,076,511.45
" " " " intercepting devices	42,500.00
" " " " power plant	460,000.00
" " " " the 25,000,000 gallon disposal plant	450,000.00
Estimated cost of the disposal plant for 1930	2,605,000.00
Total estimated costs	4,634,011.45
19.76% Increase in cost over estimate (as above)	917,680.66
Estimated administrative cost	365,009.10
Actual expenditures, (from above)	3,304,718.79

Total estimated cost of the entire system of sewers and the disposal plant for the 1930 population---- 9,221,500.00

A P P E N D I X .

ACTIVATED SLUDGE SYSTEM OF SEWAGE DISPOSAL.

Since writing the preceding articles in Part III, on Activated Sludge, and the new disposal plant, several interesting facts have been learned through experiments carried on at the testing station, regarding the disposal of sewage by the Activated Sludge Process.

The greatest defect of the experimental plant was found in the sedimentation end, and not in the aerating process, and the main problem which now confronts the engineering department is to design a sedimentation tank which will produce an uniform horizontal velocity of 3 feet per minute, or a vertical velocity of 8 inches per minute and insure the complete removal continuously of precipitated sludge as rapidly as it is formed.

The sedimentation tanks so far used, have all had a sloping bottom. A study of these, indicates that the proper slope of the bottom required to fulfill the foregoing conditions is from 1:2, to 2:3. The exact slope has not as yet been definitely determined.

A flat bottom sedimentation tank has been built, equipped with a revolving center shaft to which is attached large arms. These arms lie on the bottom and are designed to make one revolution per hour. This tank is at present in operation but as yet no definite statement, as to the results obtained, can be made.

From a careful study of the site of the proposed disposal plant, it appears that aerating tanks from 15 to 17 feet effective depth, will be the most economical to construct. All the investigations have been made upon tanks of 10 feet effective depth or less. The opinion is advanced, although with no definite data to determine the presumption that the air economy varies directly as the effective depth.

In order to study this feature a 15 feet tank has been built and will be operated in parallel with the 10 feet tanks.

The most economical methods for handling the excess sludge have not been decided, and probably will not, until experiments now under way are concluded. These experimental results should be ready by the middle of 1917.

Sludge in the sedimentation tank contains 99% water and this amount can be reduced to approximately 96% by a three hour settlement period. After passing through a "Worthington Plate Press" the sludge contains 75% moisture. A pressure press has also been used and gives similar results. The exact type of press has not as yet been definitely decided upon but undoubtedly a plate press will be chosen

From experiments conducted, the approximate cost of pressing sludge, based upon treating 100 million gallons of sewage per day, excluding overhead charges on building, is $3.46 per dry ton of sludge.

Investigations show that one million gallons of sewage when treated produces ½ ton of dry sludge. From the foregoing it would therefore cost $1.73 per million gallons of sewage, for sludge pressing.

The cost of drying and grinding the pressed sludge has been determined to be approximately $3.17 per dry ton. Drying reduces the moisture content in the sludge from 75% to 10%. Both indirect steam and direct heat driers have been used with success. Experiments are at present being conducted on driers that have been furnished by various manufacturing concerns with the object in view of choosing a satisfactory type of drier for the ultimate use.

On a basis of one million gallons producing ½ ton of sludge the cost of drying is $1.59 per million gallons, or $3.32 per million gallons of sewage treated for reducing the sludge produced to a fertilizer basis.

The value of this sludge as a fertilizer is based upon the quick availability of its contained nitrogen as NH_3. From growing experiments being carried out at the University of Illinois during the last 18 months, the availability of the nitrogen has been proven beyond any doubt and its value is equal to the same quantity of NH_3 contained in any of the high grade fertilizers.

A typical sample of dry sludge contains about 5% or 100 pounds of NH_3 per dry ton, the market value of which runs from 10 to 17½ cents per pound. Therefore, at the mimimum value there will be a net profit in the sludge disposal of between $3.00, and $4.00, per dry ton. However, if unforseen contingencies should subsequently arise which would wipe out all of this net profit and the sludge will cost as much to reduce as it can be sold for, the process will still be in advance of any other process of sewage treatment applicable to Milwaukee conditions.

Tests made on samples taken from outlets of various sewers along the Milwaukee and Kinnickinnic Rivers, show an average of 147 parts per million of suspended matters in the sewage with a nitrogen content as ammonia in the sewage solids averaging 6.8%, whereas the sewage in the Menomonee Valley Intercepting Sewer from which the sewage for the testing plant has been taken has an average of 319 parts suspended matters and the sludge contains 5% nitrogen.

That is, less sludge will be produced in the disposal plant but of higher nitrogen value than has been treated in the experimental plant on Jones Island.

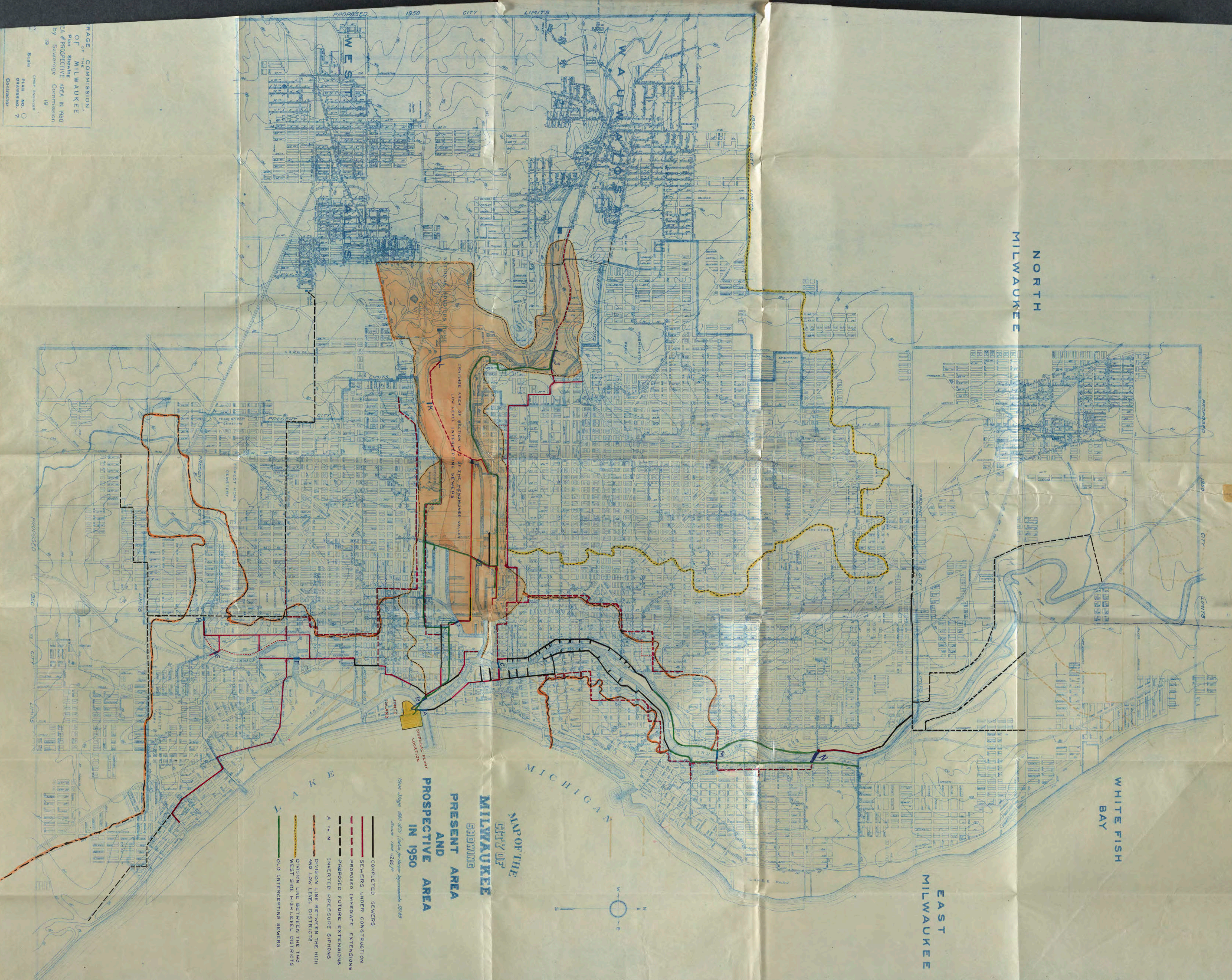
A great deal of time was expended throughout the latter half of 1916, in making studies for the ultimate sewage disposal plant and many tentative plans have been made. The general layout of the plans has been decided upon in a preliminary way; the amount and character of power which will be required and the principal features concerning the design of the power and administration buildings, and the detail design of these buildings are rapidly nearing completion.

Grit chambers, screens and operating apparatus have all been designed in detail.

It is the intention of the Commission to get the power house plans, including machinery and other equipment required, completed early in 1917, that contracts may be let and work begun just as soon as the weather will permit of this character of work being carried on satisfactorily.

As planned at present the system will require a power plant of 12,000 Horse Power. There will be three 30,000,000 gallon pumps and six 50,000 cubic feet blowers, with one pump and one blower acting as auxiliary units. Steam turbines will be used.

THE END



RAGE COMMISSION
OF THE
OF MILWAUKEE
Plan Showing
EA & PROSPECTIVE AREA IN 1950
by Sewerage Commission
19
19
Scale
CHIEF ENGINEER
PLAN NO.
DRAWER NO. 7
Contractor
PROPOSED 1950 CITY LIMITS
WEST ALLIS
WAUWATOSA
NORTH MILWAUKEE
EAST MILWAUKEE
WHITE FISH BAY
LAKE MICHIGAN
JONES ISLAND
DISPOSAL PLANT LOCATION
MAP OF THE
CITY OF
MILWAUKEE
SHOWING
PRESENT AREA
AND
PROSPECTIVE AREA
IN 1950
Mean Stage 1860-1875 (Datum for Harbor Improvements 581.63
Scale 1 inch = 1200 ft
COMPLETED SEWERS
SEWERS UNDER CONSTRUCTION
PROPOSED IMMEDIATE EXTENSIONS
PROPOSED FUTURE EXTENSIONS
A to N INVERTED PRESSURE SIPHONS
DIVISION LINE BETWEEN THE HIGH AND LOW LEVEL DISTRICTS.
DIVISION LINE BETWEEN THE TWO WEST SIDE HIGH LEVEL DISTRICTS
OLD INTERCEPTING SEWERS